FG.

(1)

79

WATER RESOURCES STUDY

Metropolitan Spokane Region

APPENDIX B

Geology and Groundwater

JANUARY 1976

METROPOLITAN SPOKANE REGION
MSR WRS
WATER RESOURCES STUDY

LIST OF REPORTS AND APPENDICES

REPORTS

Summary Report

Technical Report

APPENDIX	TITLE
A	Surface Water
B	**GEOLOGY AND GROUNDWATER**
C	Water Use
D	Wastewater Generation and Treatment
E	Environment and Recreation
F	Demographic and Economic Characteristics
G	Planning Criteria
H (Volume 1)	Plan Formulation and Evaluation
H (Volume 2)	Plan Formulation and Evaluation
I	Institutional Analysis
J	Water Quality Simulation Model

(6)

METROPOLITAN SPOKANE REGION WATER RESOURCES STUDY.

APPENDIX B

GEOLOGY AND GROUNDWATER

(12) 325p.

(11) JANUARY 1976

Department of the Army
Corps of Engineers, Seattle District

Kennedy-Tudor Consulting Engineers

KENNEDY TUDOR

410075

ACKNOWLEDGEMENTS

The Metropolitan Spokane Region Water Resources study was accomplished by the Seattle District, U.S. Army Corps of Engineers assisted by Kennedy-Tudor Consulting Engineers under sponsorship of the Spokane Regional Planning Conference. Technical guidance was provided by the Spokane River Basin Coordinating Committee, with general guidance from the study's citizens committee. Major cooperating agencies include Spokane City and County, and the Washington State Department of Ecology. The study was coordinated with appropriate Federal and State agencies and with the general public within the metropolitan Spokane area.

The summary report was prepared by the Seattle District Corps of Engineers. The technical report and appendices were prepared for the Seattle District, Corps of Engineers by Kennedy-Tudor Consulting Engineers.

PREFACE

With the enactment of the Federal Water Pollution Control Act Amendment of 1972 (Public Law 92-500), new national goals have been established for the elimination of pollution discharges into our streams and lakes. This appendix is a part of the report prepared to assist local government in satisfying State and Federal Requirements relating to Public Law 92-500. The suggestions contained in this report are for implementation by local interests with available assistance from other local, State and Federal agencies. The study suggests a regional wastewater management plan for the metropolitan Spokane urban area and provides major input to Washington State Department of Ecology Section 303e plans for the Spokane River Basin in Washington State. Also included in the study are planning suggestions for urban runoff and flood control, and the protection of the area's water supply resources.

As listed on the inside front cover, documentation for this study consists of a Summary Report and a Technical Report with supporting Appendices A through J.

The Technical Report summarizes Appendices A through J, which contain 58 individual task section reports prepared during the study. These task sections are listed by title in Attachment I of the Technical Report. Generally, the numbering of appendix task sections reflects the following system:

Study Task Sections	Type of Study Activity
300's	Data Collection
400's	Data Evaluation and Projection
500's	Identification of Unmet Needs
600's	Development of Alternative Plans
700's	Evaluation Comparison and Selection of Plans
800's	Institutional Arrangements

Pages within each appendix are numbered by task section, as illustrated below:

701.2 - 45

Task section identifier — 701.2

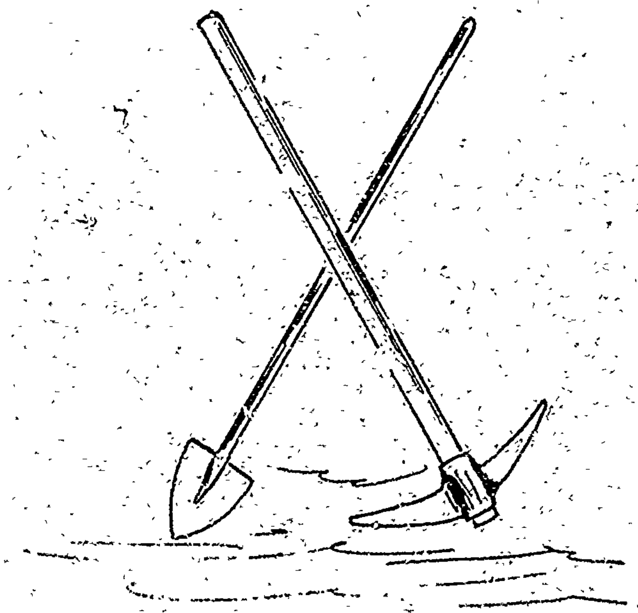
Identifies page number, numbered consecutively from beginning of task section — 45

APPENDIX B - GEOLOGY AND GROUNDWATER

CONTENTS

TASK SECTION	TITLE	PAGE
303	Geology, Soils and Groundwater	303-1 to 303-95
405	Groundwater Quality Data and	405-1 to 405-90
608.1	The Effect of Surface Applied Waters on Groundwater Quality in Spokane Valley	608.1-1 to 608.1-42

A detailed index for each task section precedes the respective section text.



SECTION 303

GEOLOGY, SOILS AND GROUNDWATER

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 303

GEOLOGY AND GROUNDWATER

Prepared by Shannon & Wilson, Inc. in cooperation with Kennedy-Tudor Consulting Engineers

1 December 1974

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

INDEX

Subject	Page
PART 1. INTRODUCTION	
Purpose and Scope	303 - 1
Method of Study	303 - 2
Preparation of Maps	303 - 2
Sources of Information	303 - 4
General Geology of Study Area	303 - 4
Engineering Geology	303 - 5
Groundwater	303 - 6
Limitations	303 - 6
PART 2. REGIONAL GEOLOGY AND GROUNDWATER	
Geologic Setting	303 - 8
Topography	303 - 8
Geologic History	303 - 11
Description of Mapped Geologic Units	303 - 18
Bedrock	303 - 19
Aeolian and Glacial Deposits	303 - 21
Recent Deposits	303 - 23
Groundwater Geology	303 - 24
Groundwater Occurrence and Use	303 - 26
Okanogan-Selkirk Highlands	303 - 27
Spokane River Valley and Gorge	303 - 29
Columbia Plateau	303 - 31
PART 3. GEOLOGY AND SURFACE SOILS OF THE SPOKANE URBAN AREA	
Introduction	303 - 33
Engineering Geology	303 - 33
Characteristics of Bedrock	
Metamorphics	303 - 35
Granite	303 - 35
Basalt	303 - 36
Latah Formation	303 - 37
Characteristics of Soils	303 - 39
Unconsolidated Glacial Deposits	303 - 39
Eolian Deposits	303 - 41
Colluvial Deposits	303 - 43
Residual Deposits	303 - 43
Alluvium	303 - 44

INDEX (Continued)

Subject	Page
Lacustrine Organic Deposits	303 - 45
Permeability	303 - 46
PART 4. GROUNDWATER RESOURCES OF THE SPOKANE URBAN AREA	
Historical Background	303 - 49
Explanation of Maps	303 - 50
The Spokane Valley Aquifer	303 - 51
Configuration of the Aquifer	303 - 51
Hydraulic Characteristics of the Aquifer	303 - 57
Use of the Groundwater	303 - 65
Interchange with Surface Waters	303 - 66
Table 1. Hydraulic Properties of the Spokane Valley Aquifer	303 - 71
List of References	303 - 73
Appendix I. Representative Water Wells in the Principal Aquifer of the Spokane Valley in Washington and Adjoining Portions of Idaho	303 - 75
Appendix II. Springs that Discharge Groundwater from the Principal Aquifer of the Spokane Valley	303 - 94
Plate Index	303 - c

PLATE INDEX*

Plate Number	Title
303-1	Geology of the Study Area
303-2	Groundwater Regions of the Study Area
303-3	Engineering Geology Legend
303-4	Engineering Geology Area 16
303-5	Engineering Geology Area 17
303-6	Engineering Geology Area 18
303-7	Engineering Geology Area 21
303-8	Engineering Geology Area 22
303-9	Engineering Geology Area 23
303-10	Engineering Geology Area 26
303-11	Engineering Geology Area 27
303-12	Surface Permeability Area 16
303-13	Surface Permeability Area 17
303-14	Surface Permeability Area 18
303-15	Surface Permeability Area 21
303-16	Surface Permeability Area 22
303-17	Surface Permeability Area 23
303-18	Surface Permeability Area 26
303-19	Surface Permeability Area 27
303-20	Near-Surface Permeability Area 16
303-21	Near-Surface Permeability Area 17
303-22	Near-Surface Permeability Area 18
303-23	Near-Surface Permeability Area 21
303-24	Near-Surface Permeability Area 22
303-25	Near-Surface Permeability Area 23
303-26	Near-Surface Permeability Area 26
303-27	Near-Surface Permeability Area 27
303-28	Groundwater Area 16
303-29	Groundwater Area 17
303-30	Groundwater Area 18
303-31	Groundwater Area 21
303-32	Groundwater Area 22
303-33	Groundwater Area 23
303-34	Groundwater Area 26
303-35	Groundwater Area 27

* All plates are large drawings bound at the end of this section.

I. INTRODUCTION

Purpose and Scope

The purpose of this report and the accompanying geologic and groundwater maps is to provide information on the geology, soils and groundwater resources of the study area.

The study area extends throughout the Washington State portion of the Spokane River Basin and consists of approximately 2,300 square miles of mountains, valleys and plateaus in the east-central portion of the State. Parts of Spokane, Stevens, Lincoln, Pend Oreille, and Whitman Counties are included. Particular attention is focused on the urban planning area centered on the City of Spokane, an area which occupies about 11 percent of the total study area.

A primary objective of this task is the preparation of general geology and groundwater maps at 1:250,000 scale (approximately 1 inch equal to 4 miles) to show in generalized form the gross geologic and groundwater features of the entire study area. This level of detail is appropriate for the portions of the study area lying outside the urban planning area. The needs of the study call for a more detailed analysis and presentation of information descriptive of the urban area. To achieve this, mapping of near-surface geology, soil characteristics and groundwater features at a scale of 1:24,000 (approximately 1 inch equal to 2000 feet) is presented for this area. The maps are supplemented by text and appendices. The text describes the history and present day features of the area in terms of geology, soils and groundwater. Spe-

cial attention is given to those features which are significant to wat .r and wastewater management.

Method of Study

Research within the study area was based upon a review of available geology, soils and groundwater data gathered in the past by a number of independent investigators. The map sets represent a compilation of these separate efforts, supplemented by imited field reconnaissance. Aerial photographs, used as stereo-pairs, provided supplemental data for the delineation of soil and rock boundaries in unmapped and poorly defined areas. Subsurface explorations, detailed field mapping or testing of subsurface materials were not performed as part of this study.

Preparation of Maps. The information compiled is presented in a series of maps, Plates 303-1 through 35. Of these, two cover the entire study area, showing respectively general geology and groundwater resources. The remaining plates contain detailed coverage of the Spokane urban planning area. Four series of plates are used to present information on each of eight mapping subareas forming the urban area, and one plate presents a legend of terms used on the engineering geology maps.

Background mapping of the urban planning area was prepared at the 1:24,000 scale from the following U.S. Geological Survey quadrangle maps.

1.	Spokane N.E.	--	1:24,000
2.	Spokane N.W.	--	1:24,000
3.	Spokane S.E.	--	1:24,000
4.	Spokane S.W.	--	1:24,000
5.	Airway Heights	--	1:24,000
6.	Greenacres	--	1:62,500
7.	Mt. Spokane	--	1:62,500
8.	Deer Park	--	1:62,500
9.	Clayton	--	1:62,500

The area immediately west of the Spokane River between the Hangman Creek confluence and the Little Spokane River confluence is not included in the large scale mapping. This stretch of river follows a natural geological boundary. The area west of the river is in the Columbia Plateau region and is adequately covered under the small-scale study area geology mapping.

The mapping of engineering geology features, Plates 303-3 through 303-11, shows the near-surface distributions and types of earth materials based on their composition and texture. Due to the nature of the source materials, the maps include reference to genetic or bedrock geology in addition to the exposed surface materials, and permit interpretation for purposes associated with engineering planning.

Two sets of maps, Plates 303-12 to19 and Plates 303-20 to 27 respectively, are presented which show the relative permeability of soils at surface depths to three feet and near-surface depths three to five feet. The purpose of these maps is to illustrate the relative ability of the soils to permit the passage of water and, in conjunction with the other map sets, to assist in the evaluation of potential problems concerning drain fields, waste disposal, groundwater contamination, runoff, or other related concerns.

Plates 303-28 through 35 define the subterranean aquifers in the

Spokane Valley plains, the terraced valley below Spokane Falls, the Hillyard Trough, and the lower valley of the Little Spokane River. Contours of the average groundwater surface elevation are also shown in these areas. Groundwater sources in the peripheral portions of the urban area are mostly minor and, because of map scale limitations, cannot be shown on the groundwater map. These areas are, however, described in the groundwater section of this text.

Sources of Information

Principal sources which were used in compiling geological and groundwater data are described below. Refer to the List of References.

General Geology of Study Area. When available, the principal source of information is the series of U.S. Geological Survey maps. These are supplemented by General Soils Maps prepared by the U.S. Soil Conservation Service, covering Spokane, Stevens, Lincoln and Pend Oreille Counties. U.S. Soil Conservation Service (SCS) mapping is the primary source for areas where geological maps are not available. Soil maps, as exemplified by S.C.S. maps, and geological maps, as prepared by U.S.G.S., are made for different purposes and often have different interpretations for similar features. Where these differences occur in the reference maps, an interpretation is made which best fits the needs of this study.

The published reports and maps of previous geological investigations used as reference material included a reconnaissance map by Griggs (1966) and maps and reports by Becraft and Weiss (1963), Cline (1969) and Flint (1936). Reports of many previous investigations of the Pleistocene

glacial history, the Latah and Palouse Formations, clay resource studies, and private well and test logs, are used to develop and confirm map data.

Engineering Geology. Large-scale (1:24,000) mapping of near-surface soil classification and drainage characteristics (permeability) in the urban area are based primarily on information from previous geologic and soils mapping. Modifications are made as necessary to suit the engineering criteria of the project maps. These data are supplemented by air-photo interpretation and limited field reconnaissance.

Previous geologic mapping in the area included the 1:125,000 scale reconnaissance geologic map of the west half of the Spokane quadrangle by Griggs (1966); a map by Cline (1969), in which a portion of the Griggs map was modified to separate certain deposits on the basis of lithology rather than age; and a 1:62,500 scale geologic map of the Greenacres quadrangle by Weis (1968). U.S. Soil Conservation Service maps of Spokane County by Donaldson and Giese (1968) provided data on soil classification and provided assistance in delineation of soil boundaries.

Where possible, formation contacts were drawn on stereo paired air photos. These were checked and completed in the field, where soils classifications were also verified on the basis of available exposures. The boundaries were then transferred to the base map via mylar tracings of the photo maps. In areas that had been previously mapped by others, checks were again made on the boundaries. Since the previous investigations were intended to show somewhat different features than the project maps, some modifications and interpretations were necessary.

In areas where drill log, test pit or other pertinent information

had been previously gathered, further checks were made. In inaccessible mountainous areas, reliance was chiefly upon air photos and previous investigations. No test pits or borings were made during this study.

Information from previous studies on soil permeability as related to grain size, together with information from Spokane County soils maps, provided basic data for the drainage maps.

Groundwater. Information on the groundwater potential of the study area is known in part by published information, but is primarily derived from a general knowledge of regional groundwater conditions and the water bearing characteristics of the various soils and rocks of the study area. Specific sources of historical information are referenced in the text. Water level records from selected wells were used to plot groundwater contours of the aquifers on the maps.

Limitations

As soil and rock formations vary considerably over both vertical and horizontal distances, boundaries indicated on the accompanying maps delineate the predominant soil or rock present in a given area. There may, of course, be several different types of soil or rock in lesser quantities within each boundary. Also, the origin of the materials within each boundary may vary locally from that shown. Furthermore, horizontal changes in soil types are often gradual; therefore, boundaries are drawn at what is considered to be midway between one soil type and another.

Because the reliability of existing available data varies and in some aspects is entirely lacking, the results presented herein reflect con-

siderable experienced judgment. The maps and accompanying discussions are not intended to preclude the need for detailed explorations and study in specific areas, but only to provide a sound basis for overall management planning.

Professional Services

This entire section on geology and groundwater of the study area was prepared by geologists and groundwater specialists on the staff of Shannon & Wilson, Inc., Geotechnical Consultants.

II. REGIONAL GEOLOGY AND GROUNDWATER

Geologic Setting

Topography. The Spokane River Basin as a complete hydrologic unit is a roughly elliptically shaped drainage area lying within northern Idaho and northeastern Washington. The total area of the basin is approximately 6,600 square miles. About 2,400 square miles of this lies within the State of Washington, and constitutes the study area. The study area's topography is dominated by the broad east-west trending Spokane Valley in Washington which becomes the Rathdrum Prairie in Idaho. The valley is flanked on the north and south by mountains, plateaus and tributary valleys. These gravelly valley plains slope gently west from mountain valleys in Idaho to the basalt ledges at Spokane Falls. Down valley from Spokane Falls, the valley plains continue only as remnant terraces along the sides of the entrenched course of the Spokane River, which follows a 60-mile canyoned course to its confluence with the Columbia River. Along its course, the Spokane River is fed by a number of tributaries, notably the Little Spokane River, Hangman (Latah) Creek and Chamokane Creek. Numerous small streams, some of them intermittent, feed into these tributaries from the highlands and plateaus.

The topography of the basin varies, from predominantly mountainous in the northern and eastern portions to rolling plains south of the Spokane River and west of Hangman Creek. The plains are a portion of the over 100,000 square mile Columbia Plateau. This plateau is formed of many horizontal lava flows of basalt and is thinly covered in places with low

hills of wind-blown silt (loess) and, in other places with glacial and flood outwash sand and gravel. North of the Spokane River Valley, remnants of the Columbia Basalt flows have formed Five-Mile, Orchard, Pleasant, Peone and Manito Prairies and Orchard and Green Bluffs. Each of these has a veneer deposit of reworked loess covering the basalt capping. Remnants of old granite mountains protrude through the basalt flows and loess south and west of the Spokane Valley.

The region generally north of the Spokane River is composed of the Okanogan bedrock highlands on the west and the Selkirk bedrock highlands to the east. The two highland areas are separated by the Deer Park Basin and the Little Spokane River valley. The highlands are subdued, mature north-south trending mountain ranges modified by glaciation. Maximum relief in the highland provinces is on the order of 4,500 feet, with local relief of about 500 to 700 feet. Elevation extremes range from 1,289 feet M.S.L. at Lake Roosevelt in the Columbia River Gorge to 5,878 feet M.S.L. on Mount Spokane.

One striking difference between the Columbia Plateau and the Okanogan-Selkirk Highlands is the character of the valleys. The basalt plateau south of the Spokane River has a gentle southward slope but drops abruptly northward at the Plateau edge causing the valleys tributary to the Spokane River to be short in length and high in gradient. These valleys are generally narrow, having been carved by limited seasonal runoff and rimrock spring flow. The topographic characteristics at the plateau edge reveal sharp breakoff slopes dissected by steep, narrow valleys. The valleys are separated by broad, relatively flat plateau segments.

Northward across the Spokane River in the granitic and metamorphic rocks of the Okanogan-Selkirk Highlands, the valleys are generally broad, rather flat bottomed, and are formed between relatively narrow, north-south trending mountain ranges. The reasons for the differences in the topography north and south of the Spokane River are twofold. The Columbia Plateau basalt flows reached their northward extent against the highlands, and also the southward extent of the Pleistocene glaciation was near the present Spokane River Gorge. Therefore, glaciation helped shape the valleys north of the river, but had little effect on the plateau area.

Differences in the topography of these two areas are reflected in differences in drainage and groundwater conditions. Surface drainage near the plateau edge is locally poor where natural drainage channels are not well established. Ponding of water is evident in small irregular basalt basins and in shallow loess pockets. However, in areas where loess cover is significant and where natural channels lead surface water to the tributary valleys, drainage is good. The drainage in the Okanogan-Selkirk highlands is generally well established along south and southwest flowing tributaries to the Spokane River. Some ponding occurs, however, in some valleys where glacial outwash or till deposits dammed up surface drainage and formed small swamps or lakes.

Other physiographic sub-divisions of the study area include the Little Spokane-Deer Park Basin, the Hangman Creek valley and the Chamokane Creek valley. Numerous natural lakes dot the basin, with Newman, Liberty, Eloika and Diamond Lakes being among the largest. These lakes are mostly

land-locked and are dammed by glacial lake, outwash, or till deposits. Other small lakes and ponds scattered over the plateau area are generally basins in the plateau basalt and represent an impoundment of water from local surface runoff.

Geologic History. The following brief summary of geologic history is intended to provide insight into the events that have produced the present geology and groundwater situation.

The oldest rocks in the basin are Pre-Cambrian age metamorphic formations which are probably related to the Belt Series of the northern Rocky Mountains. These rock formations are exposed in the northern and central highlands as well as occasional "islands" surrounded by the basalt flows on the plateaus. Many varieties of metamorphic rocks are known to occur, including phyllite, quartzite, schist and gneiss.

Large bodies of granitic type rocks of Cretaceous age have intruded into the older metamorphic rocks of the highland areas often forming large batholiths or plutons. The contact zones between the metamorphic and granitic rocks are "host" areas for many small mineral deposits known in the region. Uranium is the chief mineral presently being mined, although, in the past, copper, molybdenum, lead, zinc and tungsten have been mined in small quantities (Becraft and Weis, 1963).

The metamorphic and igneous intrusive rock masses form the mountains in the northern and eastern portions of the study area. A regional drainage course through the Spokane area during early Tertiary times (50-60 million years ago) eroded deep canyons into these rock masses. In the ancient Spokane Valley, the canyon bottom was carved to an elevation

of approximately 800 feet above present sea level elevation. The same metamorphic and intrusive igneous rock masses also underlie the rest of the basin where they are covered with sedimentary rocks, unconsolidated soils and volcanic rock flow.

Two types of Tertiary volcanic rocks occur in the study area. Of these, basalt, with its associated breccea and tuff deposits, is by far the most abundant. The other, andesite, is found at scattered locations in the western portion of the basin.

During the Miocene Epoch of the Tertiary Period, successive lava flows from huge earth fissures spread over the metamorphic rocks. Accumulation of this Miocene Columbia River basalt blocked the westward flow of rivers and streams and created large lakes in the canyons. Clay, silt and sand, eroded from weathered igneous and metamorphic mountain areas to the east, and airborne volcanic ash from the west, were deposited into these lakes. Near the north and east edges of the Columbia Plateau these deposits interbedded with some of the successive lava flows. This deposition occurred throughout much of the middle Tertiary period, and the sediments varied from fine clay deposited during quiet periods to sand and gravel transported to the lakes by floods or landslides. Leaf fossils now found in these sediments indicate deciduous forests grew along the lake shores. The sediments thus formed have consolidated into soft sedimentary rock and are now known as the Latah Formation. High "rimrock" bluffs west of Spokane and remnant mesas, such as at Five-Mile and Orchard Prairies, are typical of the interbedded basalt and Latah deposits.

After the cessation of the lava outpourings, the ancestral Spokane River carved a gorge around the north edge of the great lava field. By the beginning of the Pleistocene Ice Age, a broad valley had developed at about 1600 feet altitude. This pre-glacial drainage course apparently passed through the Spokane area either by way of a bedrock canyon in the Hillyard Trough, or what are referred to subsequently in this report as the "North Central Gap" and the "Shadle Park Gap." During the Quaternary Period, which included the Pleistocene and recent Epochs, a variety of deposits occurred. By mode of origin, they may be classified as eolian, morainal, glaciofluvial, glaciolacustrine, and alluvial.

The eolian (windblown) deposits consist of clay, silt and fine sand. Known as the Palouse Formation loess, these deposits occur as dunes and rounded hills covering most of the plateau areas. The loess soil is valuable to the economy of the area as crop land, although careful farming practices must be observed because of the high susceptibility to erosion. Among portions of the northern margin of the plateau and on the Spokane area mesas, the loess is mixed with gravel and occasional cobbles and boulders,having been reworked by stream action and deposition into glacial lakes. The thickness of loess deposits varies considerably from a few inches to almost 100 feet.

Pleistocene glaciation extended into the Spokane River basin several times, although most of the glacial features now in evidence are the result of the last ice advance, some 10,00 to 15,000 years ago. The number and extent of glacial advances and retreats has not been definitely established, as each advance and the flood water from each retreating

glacier have destroyed evidence of the preceding glaciation. However, it is generally accepted that several floods occurred from melting glaciers and the sudden outbreak of glacial lakes to the north and east of the area. The ice lobes, extending southward from the Cordilleran ice sheet, entered the Columbia River Gorge, the Colville-Chamokane Valley, the Little Spokane River Valley and the Purcell Trench-Spokane River Valley. Most recent investigations (Weis and Richmond, 1965) have concluded that ice reached further south than the plateau edge only in the Columbia River Gorge. As a result, glacial till and ice-modified topography is mostly in evidence north of the Spokane River.

Glacial lobes north of the Spokane River, primarily in the Newport-Colbert (Little Spokane River valley) and the Chamokane Creek areas, left poorly sorted, morainal deposits of silt, sand and gravel till. Most of these moraines are poorly exposed and are generally thin. Some glacially polished bedrock is also evident in these areas. In the Spokane valley, the effects of the continental glaciation of the Pleistocene epoch consisted mostly of the deposition of gravel, sand and silt, laid down by floods and melt waters from glaciers which stopped short of the valley.

Features of the glaciofluvial deposits in the Spokane River valley include widespread occurrence of sand, up to elevations as high as 2,200 feet, deposited during times when there were glacial obstructions of the regional drainage farther down stream, a preponderance of coarse gravels following along the central part of the valley, and an overall buildup of the glaciofluvial deposits to a thickness of at least 300 to 400 feet in the central part of the valley all the way to the mouth of the

Spokane River. At the depositional maximum, the glaciofluvial deposits underlaid a wide gravelly plain with an altitude of about 2,000 feet, at Spokane.

In the area affected by glaciation, mountainous terrain was modified by the removal of residual soils, talus, and highly fractured surface rock. Higher mountainous areas and other highland areas that escaped glaciation, such as Mt. Spokane, and Browns Mt., were exposed to long periods of surface weathering, largely as a result of physical disintegration from the freeze-thaw process. This has produced a thin mantle of residual soil and rock rubble over portions of these areas. A similar mantle has developed on more level basalt surfaces. In the southern and eastern portions of the study area, chemical alteration has caused deep decomposition of some metamorphic rocks.

Several times during the periods of glacial advance and retreat, lakes were formed when ice blocked main and tributary river valleys. Outwash silt, sand and gravel deposited in these lakes are now in evidence as stratified terrace and valley fills in tributary entrants and on the floors of topographic basins. Two large areas which show evidence of glacial lake sedimentation are the Deer Park Basin and an area north and east of Wellpinit on the Spokane Indian Reservation. Terraces along the lower Spokane River give evidence of other periods of glacial damming and deposition at a lower elevation. Subsequent erosion of these lake deposits has washed away all but a few terraced remnants along the valley flanks.

At one or more times during periods when lakes filled the Spokane River Valley, the lakes spilled excess water out over

the Columbia Plateau to the south. Large quantities of overflow water washed away some of the loess cover and eroded channels into the basalt plateau. During different stages of the flooding, layers of boulders, cobbles, gravel and sand were deposited over some areas of the eroded surface. In quieter times, small ponds and swamps filled with silt and clay. Today, this area, known as the "channelled scablands", reveals bare rock scablands, gravel bars, thin cobble, gravel and sand veneers, silt and clay deposits, and islands of loess to give evidence of its varied history.

Present geologic evidence indicates that several catastrophic floods occurred through portions of the study area during late Pleistocene times. These floods had a significant influence on the present day topography and geologic features. These floods, collectively called the Missoula Flood, occurred an estimated 22,000 years ago (Richmond 1965), and was the largest fresh water flood ever documented in geologic records. The causes and results of the flood have been well documented by Baker (1973), Bretz (1923, 1969), Bretz, Smith, Neff (1956), and many others.

During late Pleistocene time, a glacial lobe, at least 2,000 feet thick, blocked the mouth of the Clark Fork River in northwestern Montana, ponding an estimated 500 cubic miles of water. The lake, Glacial Lake Missoula, filled and overtopped the ice dam, causing a rapid failure of the dam and a quick release of water. The water could only take one course, down a valley in northern Idaho, which now comprises part of the Purcell Trench, and out through the Spokane River Valley. It has been estimated that the flood reached a peak flow of 752 million cubic feet per second. The entire

flood is believed to have lasted only a week or two (Baker, 1973, p. 65). Constrictions in the lower Spokane River Gorge backed the flood waters up until they overflowed southwestward over the Columbia Plateau towards the Quincy and Pasco Basins. The onrush of water scoured out the valleys along its course and eroded a wide swath of loess from the surface of the Columbia Plateau southwest of Spokane. As the flood waters spread out, slowed down, or were locally ponded, the immense quantities of materials eroded along its path were deposited in the valleys and on portions of the plateau. Much of the gravel and sand now filling the Spokane Valley and in filled channels from Spokane to Pasco Basin are believed to have been deposited by the Missoula Flood.

The present course of the Spokane River follows the path eroded across the surface of the glaciofluvial deposits during and after the last years of the Pleistocene epoch. The channel crosses bedrock spurs at Post Falls, Spokane Falls, Nine Mile and Long Lake Dams. It remains fixed in these bedrock notches even though deeper parts of the alluvial fill permit groundwater to pass around them. Up valley from Spokane Falls, the post-glacial downcutting by the river has been minimal, the last of the glaciofluvial channels being visible on the prairie surface westward to beyond the state line. Downstream from Spokane Falls, the river has cut a gorge several hundred feet into the glaciofluvial deposits. This action has resulted in notched terraces on either side of the canyon which display the depositional surfaces of the glaciofluvial sediments.

In the last 10,000 years, since the end of the Pleistocene Ice Age, the soils and rocks exposed at the surface have undergone further change.

In the valley areas, these changes include: erosion and redeposition of earlier deposits by normal stream and river activity; the formation of irregular sand dunes by prevailing southwesterly winds in the outwash areas northeast of Hillyard; and also the deposition of lake sediments and the formation of peat bogs in the Saltese Flats, and near Newman and Liberty Lakes.

Recent alluvial deposits are generally small in extent and are limited for the purposes of this study to recent clay, sand and gravel deposits in river and stream valleys. Deposition of colluvium has continued since Pleistocene times, in the form of unconsolidated soils, landslides and talus. Examples of these gravity deposits are found at the base of cliffs formed by the basalt flows that rim portions of the Spokane Valley and Hillyard Trough.

Description of Mapped Geologic Units

Two exhibits have been prepared to record the geologic features of the study area, mapped at 1:250,000 scale. Plate 303-1 shows the gross geologic features of the region. Plate 303-2 shows the features of subsurface geological structure which are significant for the purpose of analyzing the region's groundwater resources.

Map symbols are identified in the legend shown on Plates 303-1 and 303-2. For certain materials, the symbol system utilizes a capital letter first to indicate geologic origin followed by a lower case letter to indicate physical properties. In the text which follows, the legend used on the appropriate map is listed in parentheses.

Bedrock

Granite (GR): Igneous intrusive rocks in the study area are predominantly granitic and include granodiorite and quartz monzonite rock types. The symbol (GR) also indicates areas where smaller intrusions of aplite and alaskite occur. Granite is the predominant rock of the Okanogan Highlands and also occurs as "islands" on the Columbia Plateau where it is surrounded by basalt flows. The granitic rock is generally massive to locally blocky, medium gray in color, and is fine to coarse grained. It is surficially weathered where exposed, except along glacial flood scoured valley walls where it appears fresh and hard. Deep alteration and decomposition often occurs in contact zones between metamorphic rocks and intrusive rocks.

Metamorphic Rock (ME): Metamorphic rocks of the study area include phyllite, quartzite and carbonate rocks in the western portions of the study area and schist and gneiss in the eastern portions. The rocks are generally intensely metamorphosed sedimentary shales, sandstones and limestones. Original thickness of the sedimentary deposits is unknown. The metamorphic rocks have been extensively intruded by granitic rocks and have been further modified. The metamorphic rocks occur in eastern Washington in an area about 30 miles wide and 50 miles long (Weis 1968). The metamorphic rocks in the study area are surficially weathered except where scoured by glacial flood waters. Deep weathering or alteration occurs in some protected areas and near contact zones with granitic intrusives.

Columbia River Basalt (BA): Basalt of the Columbia River Group is the predominant rock of the southern half of the study area,

although there are scattered remnants of basalt in the northern half. The basalt is composed of many separate flows sometimes separated by weathered zones, or as in the Spokane area, siltstone interveds. Individual flows range in thickness from 10 feet to 200 feet and total thickness ranges upward to 1,500 feet in the study area and to 5,000 feet elsewhere on the plateau. The rock is highly jointed and blocky and talus slopes usually form at the base of most basalt cliffs. Columnar jointing occurs in some areas. Pillow lava structure is exposed at various locations, indicating lava deposition into shallow lakes. The basalt is generally dark gray to black, dense and fine grained. The upper few feet of each flow is commonly vesicular.

Latah Formation Siltstone: (ST) In the study area, the Latah Formation occurs generally east of Nine-Mile Falls, where it lies beneath the Spokane Valley gravels, the rimrock basalt, and is interbedded with the basalt flows along the flanks of the Spokane River Valley. Thickness of the formation varies considerably. The siltstone underlying the basalt may be as much as 1,500 feet thick and the interbedded deposits are generally less than 100 feet thick. The Latah Formation is primarily siltstone, but contains some clay, sand, or gravel beds and lenses. The formation is overconsolidated due to the overlying weight of the basalt flows. Colors of the siltstone range from gray to gray-brown, but upon exposure to weathering, turn to distinctive buff, white or light yellow. Many beds of the Latah Formation are fossiliferous and contain abundant imprints of plants, diatoms and sponge spicules.

Surface exposures of the Latah Formation are too small to be

mapped at 1: 250,000 scale on Plate 303-1. They are of significance to considerations of slope and local groundwater conditions in the Spokane urban area, and are mapped at 1: 24,000 and discussed in a later section of this report.

Aeolian and Glacial Deposits

Palouse Formation Loess (Wm-1, Wm-2): In the study area, Palouse Formation silt loess covers most of the Columbia Plateau south of the Spokane River and the small remnant basalt flows north of the river. The formation varies greatly in thickness due to its dune-like deposition, erosion, and the fact that it was deposited on an irregular plateau surface. Thickness varies from a few inches to nearly 100 feet. Soils of the Palouse Formation consist primarily of tan to brown silts which contain varying amounts of clay or fine sand. North of the Spokane River, the Palouse formation silt has generally been mixed or reworked with sand and gravel. When glacial lakes covered this area, sands and gravel from the highlands were deposited in the lakes, mixing with the submerged silt. In addition, gravel, cobbles and boulders trapped in floating blocks of glacial ice were deposited in the lakes as the ice melted. These deposits of reworked Palouse Formation loess are designated Wm-2 on Plate 303-1.

Outwash and Flood Deposits (G): These were carried by the large meltwater and flood releases during periods of glacial recession. The Spokane River Valley, Hillyard Trough, Little Spokane River Valley, and Chamokane Valleys received large quantities of these deposits. Thicknesses of these deposits are unknown, but estimates derived from seismic and drill

hole information indicate thicknesses exceeding 400 feet in the Spokane Valley and 700 feet in the Hillyard Trough. Flood deposits, the primary fill of the Spokane Valley, consist of relatively clean, rounded gravel with varying amounts of sand, cobbles and boulders. Outwash deposits, in Hillyard Trough, Little Spokane Valley and Chamokane Creek are generally finer and are composed of stratified silt, sand and gravel with only occasional cobbles or boulders. Outwash deposits in the Spokane River gorge west of Long Lake Dam primarily consist of silt and sand.

Glacial Till Deposits G(t): Deposits of glacial till are limited to portions of the northern half of the study area. These deposits were left by glacial lobe advances down the Spokane River Valley, the Little Spokane River Valley and a large part of the northwest portion of the study area as far south as the Spokane River Gorge. The till deposits are generally in low terminal and lateral morainal hills, and relatively flat ground moraines. The till cover is thin and rarely exceeds 30 to 40 feet in thickness. The morainal material consists of unsorted, unstratified clay, silt, sand, gravel, cobbles and boulders.

Glacial Lake Deposits (L): Glacial lake deposits occur in areas along the sides of the Spokane River Valley and Gorge, in canyons tributary to the Spokane River, and in the Deer Park and Wellpinit areas. Thickness of these deposits vary from thin edges at shorelines to as much as 300 feet. The glacial lake deposits generally consist of stratified silt and sand, but clay beds or gravel lenses do occur in most deposits.

Recent Deposits

Alluvial Deposits (A): Alluvium is deposited along most of the tributary streams of the Spokane River, although the Latah Creek, Little Spokane River and Chamokane Creek valleys are the only ones with significant accumulations. The deposits are generally thin, with the greatest thickness recorded being 38 feet in the Little Spokane Valley (Cline 1969). Alluvial deposits along the Spokane River upstream of Nine-Mile Falls are generally restricted within the river banks and to "Flood stage" gravel bars. These features are too small to map on Plate 303-1 or on the engineering geology maps at 1: 24,000 scale. The alluvium accumulations consist of silt and sand with lenses of gravel. Some clay and organic silt is also found in the meandering reaches of the lower Little Spokane River.

Residual Deposits (R): Residual materials are those formed in place by disintegration or decomposition of rock and which have not been moved beyond the local area. Residual soils and rock rubble has accumulated over much of the Okanogan-Selkirk Highland area where bedrock has been exposed. Thickness of these deposits is generally thin and probably averages less than 10 feet. However, local conditions of rock type, topography, jointing, and protection from exposure vary the degree and depth of weathering.

Residual materials commonly consist of fine to coarse sand and rock rubble from gravel to boulder sizes. Some rocks such as basalt and some metamorphic rocks have, under certain conditions, weathered to clay sized particles and occur locally within the plateau and highland areas.

Colluvium: Although not in deposits large enough to map on Plate 303-1, colluvium occurs in many places of the study area. Colluvium occurs at the base of the rimrock basalt cliffs and on the lower slopes of many highland areas. Colluvium consists of unconsolidated rock materials that accumulate by gravity or slopewash at the base of cliffs or slopes. The deposits at the base of the rimrock cliffs are primarily basalt talus and blocks, but in the Spokane region, are mixed with weathered silt from the Latah Formation interbeds. The colluvium in the highland areas generally ranges from silt to boulders and is often mixed with pre-existing glacial, alluvial or other materials. Thickness of the colluvium deposits varies upwards from a few inches to nearly 100 feet.

Groundwater Geology. Groundwater occurs in varying amounts throughout the Spokane River Basin. The largest amounts occur in the glacial flood gravels of the Spokane Valley between the Washington-Idaho state line and downtown Spokane. Lesser amounts are found in the Little Spokane River-Deer Park Basin and the Columbia Plateau. The least amounts of groundwater may be expected in the Spokane River Gorge west of Nine Mile Falls and north of the river in the bedrock areas of the Okanogan-Selkirk Highlands. The following general descriptions explain the relationship of groundwater occurrence to the geologic units shown on the groundwater geology map (Plate 303-2).

Pre-Tertiary Rocks (pTr): The granitic and metamorphic rocks of the Okanogan-Selkirk Highland province and of the Columbia Plateau "islands" are essentially impermeable. However, the weathered top (uppermost 10 to 20 feet) and joint cracks in the upper part are slightly

permeable and, in places, afford small yields of water to wells and springs. This type of perched groundwater forms the source of many small water supplies in the uplands underlain by these rocks.

Tertiary Rocks (Tcr): The geological units identified by this symbol on Plate 303-2 include materials of volcanic origin and sedimentary deposits. The volcanic materials consist primarily of basalt, in which there are local conditions which produce a waterbearing capability. The sedimentary deposits are those of the Latah Formation.

The predominantly clay and silt composition of the Latah Formation, with its resultant low permeability, makes it generally a non-water bearing unit. In places, sand beds within the Latah Formation have a higher permeability and afford limited yields from wells, adequate for household supply.

Permeable parts of the basalt of the Columbia River Group consist of the (1) rubbly tops of some of the lava flows, (2) pillow-palagonite phases formed locally where lava disintegrated by flowage into ponds, and (3) a rare occurrence of flow breccia. Where the lava is interlayered with sedimentary materials, there is less yield from rubbly flow tops and flow breccia, because the invasion of overlying sedimentary materials decreased this permeability. Because the more pervious zones generally occur horizontally, the groundwater is mostly confined, or both perched and confined.

Quaternary Deposits (Qgd & Qd): Glacial drift materials (Qgd), consisting of till, outwash deposits and lacustrine fine-grained materials, underlie several areas of the Okanogan-Selkirk Highlands.

The sand and gravel members of the drift are principal aquifers of the Chamokane Creek and Little Spokane-Deer Park Basin and other smaller valley areas. The aquifers afford small and moderate yields to many wells and springs. Many local "Pockets" of these glacial deposits in the mountain areas afford storage for groundwater and provide water for houses, camp sites, stock, wildlife and streams.

Gravelly glacial outwash (Map Symbol Qg) is the main aquifer of the valley areas including the Spokane Valley. In the Spokane River Gorge below Nine-Mile Falls, the gravel outwash is intermixed with other finer grained glacial outwash and lacustrine sand and silt deposits; in some of these down-valley areas the principal gravel outwash strata lie beneath terraces and above the level of the main water table.

Groundwater Occurrence and Use

Throughout the Spokane River Basin, groundwater is encountered in varying amounts. The occurrence is most prolific in the Rathdrum Prairie of Idaho, from the Spokane Valley glacial outwash deposits which extend downstream to the City of Spokane. The groundwater resources of the Spokane Valley Aquifer are described in a subsequent part of this section.

In addition to the principal aquifer, there are other geological formations within the study area which give rise to the occurrence of groundwater in usable quantities. These are outlined in the following text, and may be related to the information shown on Plate 303-2, "Ground-

water Regions of the Study Area."

Okanogan-Selkirk Highlands: This region, generally north of the Spokane Valley, is characterized by the occurrence of pre-Tertiary bedrock formations, the oldest in the basin. The region encloses major tributary valleys of the Spokane, including the Little Spokane-Deer Park Basin and the Chamokane Valley, which have been influenced by Pleistocene glaciation.

The water supply of the upland areas is derived principally from springs and shallow wells in "pockets" of glacial deposits and alluvium or from near surface fractured zones in the bedrock. Residences and the sites of recreation, agriculture and forest management are centered about these scattered sources of groundwater, mostly in the valley areas. The groundwater supply is sufficient only for a sparse population and for grazing and wildlife purposes. The smaller upland valleys are similarly limited. In favorable places, the larger lowland valleys have sufficient groundwater for towns and small communities. Large withdrawals, in amounts greater than about 10 million gallons per day, could exceed the capacity of the available groundwater sources unless procedures, such as artificial recharge by stored surface water, were followed. In general, future large withdrawals are feasible only in the larger valleys such as those of the Little Spokane River and Chamokane Creek, and those withdrawals will need to be wisely located and administered.

Intermountain valleys have small to moderate supplies of groundwater, primarily from irrigation, industrial and public supply wells. These wells yield in the range of 50 to 500 gpm from sand and gravel

members within the glacial drift and glacial outwash deposits. In the Chamokane Creek and Little Spokane River valleys, most households can readily obtain domestic water from nearby springs or by drilling wells 50 to 200 feet deep. Larger withdrawals of groundwater are obtainable in a few places where greater thicknesses of saturated sand or gravel occur and the sites are not too high above the valley water table.

Groundwater is contained in minor aquifers in the blocked tributary valleys containing Newman, Liberty and Hauser Lakes, the Saltese Flats and the upper Little Spokane River. The meager groundwater information which is available in these areas indicates that the gravel and sand aquifers are lenses in finer grained material; the natural water table, like the lakes, stand at higher levels than the water table in the valley aquifer, but the water levels in pumped wells draw down unlike those of pumped wells in the valley. Hence, they appear to be effectively isolated from the principal valley aquifer and, while providing limited supplies for domestic use, are not considered major sources of groundwater.

Just before the glaciofluvial episode, these tributary valleys must have been relatively narrow, with the bed of the downstream portions graded to the 1,650-foot elevation of the pre-glacial valley of the Spokane River. The filling episodes of the glacial outwash not only blocked the lower parts of these side valleys with the progressively thicker coarse deposits in the main valley, but must have caused fine grained materials to be deposited in the slack water that occupied them. The fine grained deposits in the side valleys built up to elevation 2,100

to 2,200 and lapped up onto the bedrock sides of the pre-glacial valleys. The fine grained fills across the lower parts of th valleys and, later, the insulating seals deposited within the lakes, largely isolated the side lakes to a runoff-evaporation balance within their own drainage basins.

Spokane River Valley and Gorge. From the Washington/Idaho border, the course of the Spokane River is underlain by glacial outwash deposits. Upstream of Nine Mile Falls, these deposits contain significant amounts of usable groundwater; downstream, in the Spokane River Gorge, occurrence of groundwater is relatively sparse. That part of the aquifer which is upstream from Nine Mile Falls is the source of municipal, irrigation and industrial water supplies of the Spokane urban area. This major aquifer which is the most important groundwater body in the study area, is discussed separately and in detail in Part IV of this report. A brief description is included here together with a description of the downstream or Spokane Gorge groundwater area to complete the study area overview.

The Spokane Valley aquifer, as the upstream part is designated, includes four surface physiographic units, the Spokane Valley plains, the terraced valley below Spokane Falls, the Hillyard Trough and the lower valley of the Little Spokane River. The primary flow path through the aquifer turns northward from the vicinity of Spokane Falls and passes through the Hillyard Trough to the lower reaches of the Little Spokane. The flow paths west of the Hillyard Trough are uncertain. Two gravel filled gaps are believed to exist linking the Hillyard Trough and the branch of the aquifer underlying the river valley, but their existence is not well documented. Groundwater in small amounts can be seen flowing out at river level in the "Downriver Springs" just west of the North Central Gap, in the SW 1/4 Sec. 12, T. 25 N, R. 42 E, and may be indicative of a westward

movement of groundwater. A similar situation is present in the northern ("Shadle Park") gap, but the surface of the gap is higher and is almost 200 feet above the known elevation of the water table in the Hillyard Trough. A comprehensive subsurface investigation in these gaps would be required to determine if there is a groundwater supply in these areas, presently without wells, which could augment supplies to portions of west and northwest Spokane.

Throughout the gravelly deposits of the Spokane Valley aquifer, investigation of the specific capacities of wells has shown that well yields of 400 gallons per minute per foot of drawdown are equaled or exceeded throughout the aquifer from westernmost Idaho to the basalt at Spokane. (Frink,1962).

In the Spokane River Gorge below Nine Mile Dam, groundwater supplies are developed from a variety of sources in addition to the glacial flood outwash materials. These other sources include rimrock springs, wells in the weathered top of granitic bedrock and alluvium. The rimrock springs yield small amounts of water from the base of the rimrock basalt, wherein the groundwater is perched upon the underlying, interlayered Latah silts and clays. Some of the glacial outwash contains sand members that overlie clay beds and afford small supplies of perched groundwater to wells located on the valley terraces. Aside from places where groundwater in coarse-grained outwash materials can be tapped by wells, the river gorge is generally an area where groundwater supplies may be lacking at any particular site. The southern side of the gorge, much of which is underlain by slumped parts of the Latah Formation, may be a particularly difficult area in which to obtain a water supply from groundwater.

In the Spokane River Gorge, a great variation is observed in the yields of wells, from 2,000 gpm in some riverside wells in glacial

outwash to little or no yield from some wells drilled into the Latah Formation or granite bedrock beneath the slopes of the gorge. The indication is that, should increased water supplies be required, large amounts of water may need to be withdrawn in favorable places and transmitted extensively. Large amounts of water should be available to additional users in the future by use of such distribution systems; without this distribution of water, large areas on the slopes of the gorge may be restricted to sparse, poorly-watered habitation.

Columbia Plateau: Except for a few areas which have perched water that occurs in the outwash gravel of some of the channeled scablands and that which occurs in some surficial parts of the pre-Tertiary rock outcrops, the basalt is the only source of groundwater. Wells of 100 to 300 foot depth are commonly used for household and stock supply. Common yields of wells in the basalt range from 2,000 gpm in large deep irrigation or public supply wells to 1 or 2 gpm from 100 to 300 foot deep domestic wells. The water-yielding capability of the basalt is greater where the basalt section is thicker--consisting of a greater number of lava flows--away from the plateau's northern edge and away from the edges of the inlying granitic and metamorphic rock. Because the aquifers in the basalt consist mainly of the rubbly tops of the lava flows, the yield of wells is commonly in proportion to the number of aquifers penetrated; hence, it is in general proportional to the depth of the well (Newcomb, 1959). However, the completion of a large-yielding well that draws from several horizons of different hydrostatic heads may be impractical.

The nearly horizontal layers of basalt in the Columbia Plateau province make it difficult for water on the surface to seep through the lava flows and reach the permeable horizons below; consequently, natural recharge of the groundwater through the basalt may be small and water pumped from these horizons may not be adequately replaced by natural recharge. Significant recharge from the main Spokane Valley aquifer is prevented by low-permeability Latah silt interbeds and basalts that form the aquifer boundaries. For these reasons, the groundwater in the basalt cannot be considered as a source of water supply much beyond that now extracted. Artificial recharge of the horizontal basalt aquifers can be accomplished in a practical manner only by the intra-well injection of clean purified water. While artificial recharge may provide a future method for some cheap storage of water, it is unlikely to be a source of large supplies of water. Future needs for large amounts of water in the plateau area may not be feasible from groundwater withdrawals, though the groundwater supply is adequate for many small dispersed withdrawals from household and stock wells.

Near the north and west edge of the plateau, wells may encounter much interbedded clay of the Latah Formation. This area, extending as much as 4 or 5 miles south and west of the Spokane River canyon, is an area of low well yields. In the southern part of the area, near Cheney, Rockford and Tekoa, yields of up to 500 gpm are obtained from wells 700 to 1,000 feet deep.

III. GEOLOGY AND SURFACE SOILS OF THE SPOKANE URBAN AREA

Introduction

Information on the engineering geologic and surface soil characteristics within the Spokane urban area are presented on three sets of 1:24,000 scale maps, plates 303-4 through 27. The text which follows is intended to assist in interpreting the information displayed on the maps.

Engineering Geology (refer to Plates 303-4 to 11)

Map Symbols: Map symbols used to depict soils and rock types on engineering geologic maps are not yet standardized. A set of symbols used for the maps of this study has been agreed upon by the agencies involved.

Symbols for bedrock shown on the engineering geologic maps consist of two capital letters. Unconsolidated soils are designated by a capital letter which indicates the geologic source or origin of the soil, followed by one or more lower case letters that indicate soil type. In mixed soils, where more than one soil type symbol follows the origin symbol, the first one indicates the predominant soil, followed by symbols of soils in decreasing order of quantity present. Special depositional categories are designated by lower case letters in parentheses. The following symbols are used:

Geologic Origin	Symbol	Soil Type	Symbol
Colluvial	C	Clay	c
Glacial	G	Peat	p

Geologic Origin	Symbol	Soil Type	Symbol
Alluvial	A	Silt	m
Eolian	W	Sand	s
Lacustrine	L	Gravel	g
Residual	R	Boulders	b
Manmade fill	F	Rock Rubble	r

Special Depositional Category	Symbol	Bedrock	Symbol
		Basalt	BA
		Metamorphic	ME
Talus	(ta)	Granitic	GR
Till	(t)	Siltstone	ST

In areas where one soil overlies another type of soil or rock at shallow depth, dual symbols are used. For example, the symbol $\frac{Rs}{ME}$ denotes a shallow mantle of residual sand overlying metamorphic rock. Dual symbols are only used where surficial soils are believed to be less than 5 feet deep. However, due to subsurface irregularities, it should be assumed that localized areas may have overburden depths as great as 15 feet. Because of the variation in soil depths, no depth symbol is shown.

Each soil or rock unit shown on the maps is bounded by a dashed line. Since a gradual transition usually occurs between adjacent soil types, the lines are arbitrary, but are as accurate as map scale and technique allow. Where soil units abut rock masses, and in some lake or stream deposits, the boundaries are better defined and are more accurately mapped.

Within soil boundaries, there may be small areas of different materials, as well as like materials of different origin. Mapping these areas on a smaller scale with more detail would be required for special

land use planning.

Following are more detailed descriptions of the bedrock materials and soil types found in the urban planning area. This expands descriptions which have been introduced in more general terms under study area-wide geology.

Characteristics of Bedrock

Metamorphics. The metamorphic rock exposed in the Spokane area is predominantly schist and gneiss formed from pre-existing sedimentary rocks. These rocks are intensely metamorphosed and exhibit layering and granitization. Most metamorphic rocks are believed to be related to the Pre-Cambrian Belt Series rocks of the Rocky Mountains. Physical characteristics of the metamorphic rocks vary widely over short horizontal and vertical distances. Some are highly altered by hydrothermal processes and by deep weathering. In other areas, the rock is hard and fresh. Lack of good surface exposures precludes accurate delineation of altered and fresh rock areas on the geologic maps.

In place, metamorphic rock generally provides good to excellent foundation siting. However, metamorphic rock types in the study area vary from hard massive gneiss and quartzite to highly fractured, thinly foliated phyllite and schist. Accordingly, foundation and excavation requirements must be determined on the characteristics of each individual area prior to any planned construction.

Granite. Igneous rocks that intruded the metamorphic rocks are found in some portions of the urbanizing area north of the Spokane River.

These rocks are medium to coarse grained, hard, and generally massive. Boundaries with the metamorphic rocks are often indistinct.

Weathering of the granitic rock occurs in areas of low slopes and the less exposed sides of mountain ridges. The weathering is less intense than it is in the metamorphic rocks and does not exceed 5 feet below the exposed rock surface is most areas.

Areas of granite outcropping generally are excellent for foundation siting. The rock is generally massive, but local jointing causes some blockiness. Excavation usually requires blasting below any surface residual deposits. Deeply altered zones near contact zones with metamorhpic or other igneous rock bodies may require special investigation prior to planning construction in these areas.

Basalt. Basalt is the most conspicuous rock in the Spokane area. It is in evidence at the falls near downtown Spokane, in the rimrock bluffs south and west of the city and in many local outcrops throughout the area.

Columbia River Basalt is dark gray, dense and fine grained. Basalt is inherently jointed, causing it to disintegrate and to break into blocky fragments when exposed to freezing-thawing conditions. The basalt in the Spokane region varies from slightly to highly vesicular and from moderately hard to very hard. Residual weathering of the rock is generally slight, although near the contacts with some Latah siltstone interbeds, some weathering and alteration has occurred. Thickness of individual basalt flows in the Spokane area ranges from 50 to 150 feet. The overall thickness of the successive flows ex-

ceeds 5,000 feet in some areas, but is in the order of 400 feet within the Spokane urban area.

The basalt forms an excellent foundation stratum and supports many of the larger buildings in Spokane. The surface of the basalt is highly irregular, however, and comprehensive explorations are necessary to establish the surface of the rock, prior to planning construction in such areas.

The basalt is, for the most part, impervious, although highly fractured zones occur locally, particularly near flow contacts, which permit the passage of subsurface water. Water is also encountered at the bedrock surface contact in some areas. However, the location of water-bearing zones within and on top of the basalt is often indeterminate without extensive explorations and available quantities are generally small. Seldom are they a source of groundwater supply when other sources are more readily available.

The basalt rock generally requires blasting to excavate, although large backhoes, rippers and jack-hammers are successful in highly fractured near-surface zones and for excavation "dental" work. Excavation slopes in moderately fractured basalt will stand near-vertically, but a safety area is generally required at the base to catch spalling blocks.

Latah Formation. Siltstone of the Latah Formation is rarely exposed at the ground surface, but is an important subsurface feature in the Spokane area. The siltstone ranges from soft to hard, depending upon its proximity to the surface. It ranges in color from yellow to gray brown

and often contains leaf fossils. The Latah is practically impervious, and is considered a groundwater barrier. Springs are common on the surface of the Latah where interbeds daylight on hillside slopes.

The Latah Formation is predominantly composed of silt, but has some zones of clay, sand or gravel. The Latah beds may be as thick as 500 feet below the glacial outwash gravels in the Spokane Valley (Newcomb et al., 1953) and in places rest directly upon the metamorphic "basement" rocks. Latah silts, interbedded with Columbia River basalt flows, also exist over a wide area adjacent to the Spokane River Valley, but the interbeds are generally less than 100 feet thick. Pardee and Bryan (1926) state that the Latah Formation may be as much as 1,400 to 1,500 feet thick in the vicinity of Hangman (Latah) Creek.

Near the surface of many beds, the Latah siltstone has softened to the consistency of a stiff soil. At depth it is highly overconsolidated. The Latah, in general, is considered an excellent foundation stratum, although local groundwater conditions and the degree of natural softening may dictate special foundation considerations in certain areas. Excavations into the Latah can generally be made with conventional power excavation equipment.

There have been very few man-made cuts in the Latah and very little direct evidence of recent landslides or failures in the natural slopes where the Latah is exposed at the surface. Where earth movements have been observed, they generally have involved the soils overlying the Latah, or were confined to the softer, weathered near-surface silts. In either case, groundwater was also involved. There is also limited evidence

of ancient movements, such as fissures and offsets, in some areas. Without direct data or experience, man-made modifications to slopes underlain by the Latah silts should be preceded by careful study.

Characteristics of Soils

Unconsolidated Glacial Deposits. The dominant soils in the Spokane Valley area are sands and gravels deposited by glacial activity. The gravel and sand in the urban section of the Spokane Valley is poorly sorted, fine to coarse, and contains cobbles and boulders. These soils were deposited from glacial flood waters, and are relatively free of silt and fine sand, except in the upper 3 to 5 feet where the finer materials generally fill the voids of the coarser sands and gravels. The permeability of these soils is high, allowing for high groundwater yield. In the Spokane Valley area, the coarse sands and gravels are believed to extend to a depth of about 400 feet below the surface at the Washington-Idaho state line, to an elevation of 1,600 feet. This estimate, however, is based upon interpretive seismic data (Newcomb et al., 1953), since to date (1973) no boring has ever penetrated through the stratum.

Glacial outwash deposits adjacent to Fivemile Prairie and in the Hillyard Trough are finer grained than those in the Spokane Valley. These deposits consist mainly of stratified sand with minor amounts of gravel and silt, and, in places, occasional boulders. Stratification and sorting of these materials, which exhibit some crossbedding, are moderate to well developed. The Hillyard Trough deposits are known to exceed 780

feet in depth (Rieber and Turner, 1963) and to become thinner north of Mead (Cline, 1969) in the Little Spokane River Valley.

Other glacially derived deposits were formed when sand and gravel-laden glacial outwash streams deposited their loads in a lake that formed behind a glacial lobe at Long Lake (Richmond et al., 1965). These deposits are classified as lacustrine sand (Ls) on the geologic maps and are located north of Mead and on the uplands flanking the Spokane and Little Spokane Valleys. These deposits are generally stratified, well sorted and flat lying and are finer grained than those in the main valley. Though chiefly sand, these deposits may contain occasional gravel or silt interbeds. Occasional ice rafted erratic boulders up to 10 feet in diameter are found in the lake sands. These deposits range in thickness up to 300 feet (Cline, 1959) and vary widely in permeability.

Other glacially derived deposits in the study area are relatively minor. Glacial moraine materials (till), consisting of unsorted clay to boulder size materials, are presently found mixed with glacial outwash, colluvial and eolian soils along the lower flanks of the Spokane Valley. According to Weis and Richmond (1965), a glacial lobe reached the vicinity of east Spokane. Because the mixing of materials from different sources often makes identification difficult, glacial till may be included in map units designated as colluvium.

The sands and gravels in the main valley are excellent foundation soils, while the finer sands in the northern portion of the urbanizing area and Hillyard Trough are excellent for most one and two story structures. Since large variations in the relative density of the finer

sands occur, study of individual sites is advisable prior to constructing large structures. Foundations for such structures may have to penetrate several feet beneath the surface.

Most of the unconsolidated glacial deposits can be excavated with conventional excavating equipment, although large boulders may require special handling. Excavation slopes steeper than about 1 vertical on 1 horizontal generally require shoring. The finer sands will exhibit apparent stability when excavated at near-vertical slopes, but such stability is temporary and unpredictable.

Eolian Deposits. Windblown silt and sand deposits are prevalent in the Spokane region. Silt occurs as loess in the Palouse Formation, and mixed with glacial sand deposits, and dune sands also occur in the area near Mead. The silts of the Palouse Formation are identified on the geologic maps by the symbol Wm-1. The mixed loessial and glacial soils are designated Wm-2 and the dune sands by Ws.

Loess of the Palouse Formation is fine grained, tan to brown silt with occasional clay and fine sand. The silt is generally indistinctly stratified and has poor permeability. Loess is characterized by many fine, usually vertical root tubules and root remnants. Thickness of the loess deposits varies greatly as a result of the highly irregular surface of the rock that generally underlies it and because of the dune-like character of the windblown deposits. Thickness of the loess in the Spokane area is on the order of 3 to 20 feet, although a test hole on Orchard Prairie (Cline, 1969) encountered a thickness of 73 feet. South of the urbanizing area, the thickness of the Palouse Formation sometimes

exceeds 100 feet (Scheid et al., 1954).

Palouse silts are a marginal foundation soil and, while adequta for light structures, heavy loads often require special foundation treatment or deeper excavation. Permeability of the silts is poor, although the presence of vertical root tubules in some areas may provide a high degree of vertical permeability. Shallow excavations in the silt will generally remain stable at near vertical slopes, while deep unsupported slopes require flattening. Local groundwater conditions such as springs usually require special slope treatment.

Deposits of loess in the uplands surrounding Spokane Valley and Hillyard Trough occasionally contain glacial sand and gravel which indicates a mixing with more recent glacial lake or glacial till deposits. The properties of the mixed soils are difficult to generalize because the degree of mixing and relative proportions of each component will significantly affect the engineering characteristics. Drainage, however, is considered poor.

Windblown fine sand has formed dunes near Mead in the northwestern area. This sand is blown from glacial outwash and lake deposits and the maximum depth of accumulation is approximately 50 feet. All windblown deposits in the Spokane area are highly susceptible to surface erosion from both wind and water.

Like the silts, the windblown sands have marginal foundation properties. All excavations require flattening of unsupported slopes. Permeability of the dune sands is generally variable depending upon the proportion of silt mixed with the sand.

Colluvial Deposits. Colluvium consists of accumulations of unconsolidated mixtures of soil and rock and is generally found on the lower slopes and at the base of cliffs. The colluvial soils vary widely and may include slopewash silt, sand and gravel, similar residually formed materials, and talus from rock cliffs. These materials may often overlap at their contacts with glacial outwash, till or with the underlying formation.

A colluvial feature peculiar to the Spokane region is the occurrence of basalt "haystacks" downslope from the basalt rimrock cliffs. The "haystacks" are basalt blocks that have broken from the flow edges and have moved downslope by gravity. In most instances, the blocks are resting on, or are partially buried in, the underlying Latah Formation. The term "haystack" was derived from the characteristic rounded shape. Haystacks range in size from 2 feet to more than 100 feet in diameter. Griggs (1966) has mapped these features as landslides but, because they are predominantly colluvian in origin, they have been mapped as colluvium for this study.

The highly variable nature of the colluvial soils precludes generalization of engineering properties. However, since most colluvium occurs upon or at the base of slopes, sites underlain by these soils are generally the most difficult to develop. Studies of the specific site condiitons in colluvial areas must be made and foundation, drainage and excavation requirements must be tailored to these conditions.

Residual Deposits. Residual deposits of the area are formed by weathering and in-place decomposition of the granitic and metamorphic

rocks of the mountainous regions. Generally, the soils remain essentially where they were formed and consist primarily of silty sand and gravel size particles, although larger pieces of rock rubble are common. The residual soils in inaccessible mountainous areas were mapped from aerial photographs and the soils classifications were interpreted from soils maps (Donaldson and Giese, 1968). Thickness of residual soils is mostly unknown and probably varies considerably. However, examination of roadcuts and stream banks indicates that depth of residual soils ranges from 1 to 5 feet, with depths up to 15 feet locally.

Residual soils generally are suitable for foundations and, when questionable, good foundation rock is usually available at reasonable depth beneath them. Excavation of residual soils can usually be accomplished with conventional excavating equipment with heavier rippers being required where the rock-to-soil breakdown is not yet complete. Because of the high silt and clay content of the residual soils and their proximity to the underlying parent rock, the permeability of these soils is generally found to be low. Water may be encountered seasonally at the residuum-bedrock contact.

Alluvium. Soils mapped as alluvium are silts, sands and gravels that have been deposited along stream valleys, chiefly the Little Spokane River and Latah Creek. These deposits vary widely in composition and are generally stratified. Thickness of the alluvium deposits is rarely over 30 feet. Alluvial deposits often merge into glacial outwash or lacustrine materials.

Because alluvium generally occurs as a variety of soil types and often in conjunction with materials of different origin, the engineering properties vary. Generally, the finer grained alluvial soils are unsuitable, or at best marginal, foundation soils, while the coarser sands and gravels are adequate. Excavation stability is usually poor as most alluvium occurs in areas containing a high water table. Sites underlain by alluvium should be investigated in detail prior to planning construction.

Lacustrine Organic Deposits. Saltese Flat, Newman Lake and Liberty Lake are shallow basins of deposition for soils washed down from adjacent mountainous areas. Plant growth in swampy areas around the basins has accumulated and, over a period of time, has formed peat bogs and organic silt deposits. These areas are soft and spongy and characterized by high water tables.

Three types of peat have been identified at each site (Rigg, 1958). Muck is peat that has decomposed to the point where plant remains are indistinguishable and usually forms a very soft surface layer of from 1 to 5 feet deep over underlying deposits. Fibrous peat generally underlies the muck and thicknesses range up to 15 feet. Fibrous peat is composed of coarse grasslike plant remains that are incompletely decomposed. Sedimentary peat is composed of small plant remains (algae, diatoms, etc.) and the remains of aquatic animal and bacteria life that have been deposited in water. Sedimentary peat is often very soft and plastic. This type of peat is found near the bottom of the deposits at Saltese Flat and Newman Lake.

The organic deposits are not suitable foundation soils and must

be removed or foundations must penetrate through them. They are soft and compressible and surface loads such as embankments will often produce settlements of several inches that may continue over a period of several years. Excavation of the peats generally requires a dragline.

Permeability. (Refer to Plates 303-12 to 27.) Two sets of permeability maps have been prepared to illustrate the relative ability of the surface and near-surface soils to transmit water. One set, designated "Surface Soils" (Plates 303-12 through 19), denotes the relative permeability of the soils from the surface to a depth of about 3 feet, while the set designated "Near Surface Soils" (Plates 303-20 through 27) presents similar data on the soils at a depth of about 5 feet below the surface.

The engineering parameter used to describe the ability of a soil to transmit water is called the "coefficient of permeability." The one that was selected for the purpose of this study is Darcy's coefficient "k", which represents the saturated flow velocity of water through a unit area of soil under a hydraulic gradient of unity. The coefficient is expressed as a velocity with units in the metric system (centimeters per second). Permeability varies over a wide range and, within the soil spectrum, can vary from about 100 cm/sec. for coarse gravels to 10^{-10} cm/sec. for highly plastic clays. The permeability of a particular material varies according to particle size, particle shape, particle orientation, density and stratification, so that values may vary widely even for a given type of soil. Field and/or laboratory tests are required to establish realistic values for given soils and soil strata with certainty. Informa-

tion regarding such tests is lacking for the soils in the Spokane area. For the purpose of this study, permeability evaluation was based upon three very broad classifications: 1) Good; 2) Poor; and 3) Practically Impervious, corresponding to permeability coefficients of: 1) greater than 10^{-4} cm/sec.; 2) between 10^{-4} and 10^{-6} cm/sec.; and 3) less than 10^{-6} cm/sec.

In terms of the soils found within the Spokane Urban area, the permeability and soil type relationship is as follows:

Permeability Classification	k (cm/sec.)	Soil Type	Typical Geology Map Symbol
Good	10^{-4}	Sands and Gravels relatively free of silt and clay particles.	Gg, As, Ls, Cs/g, Gs, Rs, Ws
Poor	10^{-4} to 10^{-6}	Very fine sands, silty sands and gravels, silts.	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
Practically Impervious	10^{-6}	Clayey silts, rock	Ba, ST, Am, Lm

The primary basis for the permeability/soil type relationship tabulated above is the U.S. Soil Conservation Service (U.S.S.C.S.) soils data for Spokane County presented by Donaldson and Giese (1968). Permeability in the U.S.S.C.S. publications represents an infiltration rate expressed in inches per hour, through a unit area of soil under a given head, usually 0.5 inch (U.S. Department of Agriculture, 1951). A limitation of the U.S.S.C.S. data for Spokane County is that they are based upon only a few tests with the majority of the permeability values being assigned on the basis of a visual classification of the soil. Further, the U.S.S.C.S.

system contains several categories, spanning a relatively narrow portion of the total permeability spectrum, which may be unrealistic if unsupported by direct testing. Therefore, only the relative magnitudes of the published data were considered and judgment was applied on the basis of the grain size characteristics presented by the U.S.S.C.S., particularly that portion passing the No. 200 mesh seive, constituting the portion of silt and clay particles.

Boundaries on the surface drainage maps generally coincide with those on the engineering geologic map. However, because different soils may have similar drainage characteristics, fewer boundaries are used. Like the soils boundaries, the drainage boundaries are arbitrarily drawn, consistent with the scale and technique used.

IV. GROUNDWATER RESOURCES OF THE SPOKANE URBAN AREA

Historical Background

From the times of pioneer settlement, springs and shallow wells were the most popular early-day means of supplying water. The first public supply at Spokane was pumped from the river at Havermale Island. The system was promoted by a private company, but was taken over by the City of Spokane in 1885, a few months after supply was initiated. Nine years later, the capacity of the system was enlarged, and the source moved upstream to Parkwater.

The City looked to groundwater sources when further expansion of supply was contemplated and installed its first groundwater pumps in dug wells at Parkwater in 1908. The main gravel aquifer of the Spokane Valley plains has provided essentially the entire supply of domestic, public service, industrial and irrigation water for the Spokane Urban area. Spokane is now the largest city in the nation to rely entirely upon groundwater sources for its public water supply.

In spite of the early reliance upon underground sources of water supply, little was known of the extent and properties of the Spokane aquifer until the early 1920's. It was then that the first studies were begun by the Washington Water Power Company to learn more about the regimen of the water available for electric power generation. The data and interpretative results of their efforts, reported by E. R. Fosdick (1931) have since been substantiated and expanded by later studies by several public agencies. Pertinent data from these later studies are given by

Weigle and Mundorff (1952) in Washington and by Nace and Fader (1950) in Idaho. The principal presentation of engineering data for well design is contained in Frink's 1962 paper for the Bureau of Reclamation.

Explanation of Maps

Features of the principal subsurface aquifer in the Spokane urban planning area are presented on a series of eight maps, Plates 303-28 through 303-35.

The groundwater maps show the average summer elevation of the groundwater table within the principal aquifer of the Spokane Valley, the Hillyard Trough and in the lower valley of the Little Spokane River. Water level records from selected wells were used to derive the groundwater contours of the aquifers shown on the maps.

The well records used as a data source are presented in Appendix I. Well locations are shown on the groundwater maps. The wells listed in Appendix I are those whose records afford reliable water level information over an extended period of time and are strategically located within the study area. Some of the wells shown on the maps represent a group of closely-spaced wells. In such cases, the one with the best level record has been selected. Most of the wells listed in Appendix I were constructed prior to 1952. The reason for this selection is that wells with good long-term water level information were considered to be the most valuable data sources. The data further indicate that there has been no significant change in the water table during the last 20 years.

A small part of the groundwater discharges from known and named

springs. These are described in Appendix II and are located on the groundwater maps.

Lateral boundaries of the aquifers are shown on the maps, although their location is only approximate. The elevation at which the water table intersects an impervious barrier is considered to be the aquifer's lateral boundary. In the Spokane area, the aquifer boundaries are normally sloping bedrock or Latah Formation preglacial channels.

The Spokane Valley Aquifer

Configuration of the Aquifer. The principal aquifer consists of a massive body of glacial outwash sands and gravels that underlies the Spokane Valley in Washington and the Rathdrum Prairie in Idaho. The principal aquifer branches at Spokane Falls, with one branch following the route of the lower river valley and the other passing through the Hillyard Trough to the lower Little Spokane River Valley. The general outline of the glacial materials which constitute the aquifer is indicated on Plate 303-2. Within the study area, the glacial outwash extends along the Spokane River to within 10 miles of the confluence with the Columbia River, and fills the Chamokane Valley.

The detailed description which follows refers only to that portion of the aquifer lying within the urbanizing area—between the Idaho border and the confluence of the Spokane and Little Spokane Rivers, at the head of Long Lake. Within this area, geologic and hydrologic data is relatively plentiful, by contrast with the more westerly portions of the Spokane Valley.

Through the central part of the Spokane Valley the aquifer consists of very permeable coarse gravel and sand that contains beds of boulders and cobble size as well as boulders and cobbles scattered through finer gravel. The materials are so bouldery that, prior to World War II, wells were dug and masonry curbings were handlaid more cheaply than machine drilling could be done. Even after machine drilling became the usual practice, most wells were not drilled more than a few tens of feet below the water table. Consequently, there is little drilling information on the materials in the lower part of the aquifer, below a depth of about 50 feet.

The high permeability of at least the upper part of the aquifer is known to continue west to the area of the basalt at Spokane Falls. Northward through the Hillyard Trough, the aquifer materials are progressively finer grained; sand and even fine sand and clay beds become an increasing part of the materials below the water table toward the northern end of the Hillyard Trough. Throughout the aquifer, finer grained materials have been encountered in a number of drillings. One test well, 1/4 mile south of the Spokane City Well Field at Parkwater, is said to have been drilled 111 feet deep to an elevation of 1,842 feet, and abandoned because sand predominated below a depth of about 60 feet (Weigle and Mundorff, 1952). A 6-inch test well at the Diamond Match Company at the eastern side of Spokane (E 1/2 Sec. 14, T25N, R43E) is reported to have been drilled 90 feet deep to elevation 1,780 in saturated gravels and solely in "clay" to an unreported depth below elevation 1,780 (Newcomb,

1933). The well drilling records of Phillips et al (1962) and Crosby et al (1968, 1970, 1971) show rare clay or silt lenses were found in their wells and much of the sand and gravel encountered in the drilling contained 2 to 5 percent of materials in the silt and clay particle sizes.

The glacial outwash and flood materials which constitute the Spokane Valley aquifer extend to abut the sloping sides of the pre-glacial bedrock valley. In places, the gravel grades laterally into less permeable materials of outwash age; one place being at the Pasadena Park Elementary School, where reworked Latah materials interbedded with glaciofluvial sand and gravel near the side of Spokane Valley have been reported by Phillips, et al (1962). Thus, the lateral boundaries of the main gravel aquifer mostly consist of abruptly sloping surfaces of essentially impervious granitic and metamorphic rocks, slightly permeable Latah Formation and basalt with generally low but irregular permeability. In a few areas, the lateral boundaries include fine-grained outwash and other sedimentary deposits of outwash age which limit the width of the gravel aquifer. These boundaries between the aquifer and finer grained sedimentary deposits occur mainly across some of the larger tributary valleys, such as those containing Newman and Liberty Lakes. The dividing line between the coarse materials of the valley aquifer and the fine-grained fill across these side valleys is only generally known from records of a few wells.

One significant deficiency in information on the boundaries of the aquifer occurs in the northwest part of Spokane where two gravel-filled gaps exist in the western side of the Hillyard Trough. The out-

cropping area of the basalt ledge, over which the river falls at Spokane, extends north nearly one mile to the vicinity of North Central High School. Between that end of the basalt and a 1/4 square mile knob of basalt, centered at Courtland and Elm Streets, a one-mile sag in the drainage divide is underlain by gravel. To the north of the basalt knob, another gravel-filled gap 1-1/2 miles long extends through Shadle Park and north to the slope which rises to Five Mile Prairie. These two gravel-filled gaps are shown on Plate 303-32, as "North Central Gap" and "Shadle Gap," respectively. While there is a lack of information in these areas, either or both of these gaps are suspected of serving as conduits for the westward movement of groundwater which has been inferred from river flow measurements described later in this report.

Plates 303-28 through 303-35 show the lateral boundaries of the aquifer, at the elevation of the water table, within the Spokane urban planning area subject to the limitations of data described above.

Knowledge of the thickness of the valley aquifer is derived mainly from geologic interpretations, drillers' logs of a few wells that have been drilled through the aquifer along the sides of the valley, two seismic cross sections (Newcomb _et al_ 1953), and two deep wells drilled by the Washington Water Power company and the Bonneville Power Administration in the Hillyard Trough.

The seismic section across the valley just east of the Idaho State Line indicates that the base of the glaciofluvial gravels rests on material typical of the Latah Formation, which has low permeability. The aquifer, some 3 miles wide, averages a depth of over 400 feet below ground

surface. The seismic information shows that the base of the aquifer is in the form of two broad "channels," the northern one being the deeper and reaching down to elevation 1,600. The average elevation of the aquifer base inferred from the seismic survey is about 1,690, approximately 300 feet below the water table for this section of the valley (Newcomb et al 1953).

A partial check of the validity of the seismic data was provided by a test well drilled for the Bureau of Reclamation a mile to the west of the seismic section. This test well was near the state boundary in the middle of the valley and near the site of the Bureau's "Site 11" area which is in the NW 1/4 SW 1/4 Sec. 31, T26N, R46E. The test well was drilled to a depth of about 300 feet, or within about 100 feet of the aquifer base as inferred by the seismic survey, and did not reach the base of the glaciofluvial gravel aquifer. At a few places along the edges of the valley, wells have encountered the sloping top of the bedrock (granitic, basaltic or Latah sedimentary rocks) before reaching the level of the water table in the gravel aquifer, but no well is known to have been drilled completely through the aquifer in the central part of the Spokane Valley.

The seismic section across the Hillyard Trough shows the base of the valley gravel aquifer is an essentially even surface at a depth of some 300 feet, at elevation 1,700 (Newcomb et al 1953). The water table is at about 1,820 feet elevation indicating that the depth of groundwater flowing in the aquifer is approximately 120 feet through this section of the Hillyard Trough. At the north end of the Hillyard Trough

the base of the aquifer, below elevation 1,650, is believed to be uneven and be partitioned by bedrock spurs, based on observation of the ground-water discharges to springs and to the Little Spokane River at elevations ranging from 1,620 to 1,540 within a lateral width of some 2 miles.

A test well for the Washington Water Power Company was drilled in 1962 through the gravel aquifer in the Hillyard Trough. The well, located in the NE 1/4 SE 1/4 Sec. 20, T26N, R43E, 1000 feet north of the seismic line, was drilled to a depth of 780 feet. Because the well was drilled to test the sub-aquifer section for gas storage possibilities, a record of the aquifer materials was kept only on a nearby water well (26/43-20J1, in Table I-1, Appendix I). However, the sub-aquifer samples start at 345 feet depth, the depth reported on the seismic section as the base of the aquifer. From 345 to 715 feet the well was drilled in clays, silt and sand. Cobbles and boulder gravel were reported from 715 to 780 feet. The description of the clay, silt and sand appears to show that this section of the drilling penetrated sedimentary materials of the Latah Formation, but the report on the drilling (Rieber and Turner, 1963) concludes that the material was of Pleistocene age. The cobble and boulder materials from 715 to 780 feet may have been a basal conglomerate of the Latah Formation, as the seismic section interprets granitic bedrock at a depth of about 740 feet. A mile north of the seismic section, a water well drilled for the Bonneville Substation near the center of Section 16 shows the base of the sand aquifer at 272 feet depth, 20 feet below the elevation of the base at the seismic section a mile to the south.

Thus summarized, data on the base of the gravel aquifer of the

Spokane Valley and the Hillyard Trough indicates a wide planar pre-glacial surface sloping gently westward to Spokane where the altitude of the base is unlocated but presumed to be near or below elevation 1,650, 190 feet below the basalt rim over which the river flows. The possible higher elevation of the base of the aquifer in the northern part of the Hillyard Trough may indicate that the base of the main course of the gravel aquifer trends west through one of the two gaps in the basalt rim south of Five Mile Prairie. Also, this higher base of the aquifer in the northern part of the Hillyard Trough suggests that the sand and gravel deposits of the northern part of the Hillyard Trough were laid down by southward flowing outwash streams tributary to the meltwaters coursing west through the Spokane Valley. The base of the aquifer may be underlain largely by the Latah Formation, but knobs, spurs and "islands" of the granite bedrock form the base of the aquifer in places.

Hydraulic Characteristics of the Aquifer. East of the study area, the aquifer extends into Idaho, where the elevation of the water table at its extreme northern end is influenced by Lake Pend Oreille. Prior to 1952, the natural level of the lake was at elevation 2,051. From this elevation, the water table had a gradient of about 2 to 2-1/2 feet per mile beneath the valley plains in the Athol, Idaho area to within about 5 miles of the State line. The gradient of the water table for the 5 miles east of the State line was 5 feet per mile (Newcomb, 1933). With the closure of Albeni Falls Dam in 1952, the normal pool level of Pend Oreille Lake was raised to about 2,059 feet, and the level of the water table in the North Pole and Athol areas adjusted to the new level.

Depths to the water table at the northern end of the aquifer in Idaho are in the order of 300 to 400 feet. At the Washington/Idaho state line, the water table lies near elevation 1,980, about 100 feet below the surface of the valley plain. In its 20-mile course from the state line to downtown Spokane, the surface of the water table drops 120 feet, at slopes varying locally from 4 to 10 feet per mile. The depth of the groundwater below the surface of the valley as it approaches the City of Spokane is in the order of 40 feet, and at a few locations, sand and gravel quarry pits penetrate beneath the water table. West of Greenacres the surface of the water table is at a higher elevation than the bed of the Spokane River channel, a factor which has a significant bearing on the transfer of water between the aquifer and the river.

At the basaltic rock ledge which forms Spokane Falls, the principal branch of the aquifer is that which turns north through the Hillyard Trough. Along this course, the water table slopes evenly at about 10 feet per mile from the 1,860 feet elevation which prevails immediately east of Spokane Falls, and then steepens to as much as 70 to 80 feet per mile near the spring areas in the Little Spokane Valley. As the terrain rises from Spokane Falls to the north into Hillyard Trough, the depth to groundwater increases to about 150 feet.

From the spring areas westward down the Little Spokane River, the water table drops from elevation 1,600 to elevation 1,540 at the confluence with the Spokane River below Nine Mile Dam. The groundwater in the sand and gravel underlying the floor of the Little Spokane River Val-

ley is joined, near the mouth, by groundwater contained in the other branch of the aquifer which follows the course of the Spokane River.

This second branch of the gravel aquifer begins below the rock ledge of Spokane Falls and apparently receives some groundwater that percolates through gravel-filled gaps in the largely impervious materials that form the west side of the Hillyard Trough. Beneath the Peaceful Valley area, just west of the basalt obstruction at Spokane Falls, the water table is at elevation 1,740. From there it slopes about 15 feet per mile, in general conformity with the river's gradient, to reach the 1,602 foot level of the pool behind Nine Mile Dam. The granitic constriction that caused Nine Mile Falls, and serves as a foundation for Nine Mile Dam, forms an obstruction which results in the steep descent of the water table to the 1,540 foot elevation at the mouth of the Little Spokane River referred to above. The resulting high gradient in the groundwater accelerates percolation through the gravel east of the granite knob, especially during rising stages of Nine Mile Reservoir, as described by Broom (1951).

Over a period of years, studies have attempted to determine the patterns and quantities of groundwater flow within the aquifer, and the water balance between the surface and sub-surface flows. The principal sources of information are flow records of the Spokane and Little Spokane Rivers, which indicate that these streams gain and lose increments of flow which must represent an exchange of flow within the subsurface aquifer. The exchange can be observed at numerous springs in the gaining reaches of the river valleys. The increments of flow are sub-

ject to pronounced seasonal and year-to-year variations, as a result of the interaction of the elevations of the water table and the river profile (Fosdick, 1931; Broom, 1951). The mechanism is, however, complex, and has defied several attempts at compilation (McDonald and Broom, 1951).

A comprehensive approach to the estimation of average flows was adopted by Pluhowski and Thomas (1968), who analyzed 50 years of streamflow records. They reasoned that "below the City of Spokane, the river flows on nearly impermeable basaltic bedrock, so that virtually the entire water yield of the Spokane River basin is measured at the Long Lake gage." For the upstream end of the study area, they developed an estimate of the sources in Idaho contributing to flow in the aquifer near the State line is as follows:

		Average Flow (c.f.s.)
Infiltration from Pend Oreille Lake (approximate)		50
Infiltration from Coeur d'Alene Lake and Spokane River above Post Falls	250)	370
Infiltration from Spokane River (Post Falls to Otis Orchards)	120)	
Infiltration from streams draining onto the valley floor and precipitation on the valley floor		530
Infiltration from irrigation with surface water		50
		1,000

The magnitude of this estimate is consistent with the conclusions of

Piper and La Rocque (1944) and the flow increments to the Spokane River observed by Fosdick (1931) and Broom (1951).

With the aid of the seismic data referred to previously, estimates of the permeability and transmissivity of the aquifer can be made, and compared with conclusions reached in the course of well pumping tests. The computations are to be found in Table 1, and indicate transmissivities of 25.4 million gallons per day per foot at State Line, and 1.9 m.g.d/ft. in the Hillyard Trough.

Determinations of transmissivity by the U. S. Geological Survey from six well-pumping tests in Spokane Valley are reported (Frnk, 1962) to have ranged from 1.3 to 13 m.g.d/ft. Pumping tests were run on many of the wells in the eleven tested areas of the Bureau of Reclamation in the eastern part of the Spokane Valley and yielded transmissivity values ranging from 6 to 13 m.g.d/ft. (John W. Frink, personal communication, 1973). Each of the wells tested by the Geological Survey and Bureau of Reclamation penetrated only part of the aquifer.

The estimates of permeability and transmissivity given above and the comments on the relative permeability of geologic units concern mainly the horizontal direction. In water-laid materials, the permeability in a vertical direction is generally less than that in the horizontal, and the numerical comparison varies greatly with the type of material and horizontal layering - from one-half the horizontal permeability in clean sand and gravel to as little as one-ten-thousandth in finely bedded fine grained materials." Though an estimate of the vertical permeability of the Spokane Valley aquifer might be

within the range of one-half to one-tenth the horizontal permeability, the figure is largely irrelevant because the known movement of water vertically to the water table is by unsaturated transfer and not by vertical saturated percolation.

Except for some areas of silty soils on some of the terraces and a general incomplete silt and sand filling of the gravel interstices in the top 5 feet of the subsurface, the gravel and sand above the water table is readily susceptible to the transfer of water downward from the surface. Air moves through the coarser gravel members during changes in the atmospheric pressure, and some depletion of capillary moisture must take place by evaporation; however, this evaporative loss from the subsurface is estimated to be a small part of the infiltrated water, probably much less than 10 per cent.

Westward from Post Falls, where the river descends 120 feet to the level of the water table at Greenacres, the river is subject to continuous infiltration losses which recharge the groundwater. The resultant river losses are especially large when the river is rising rapidly. Unrecorded visual tests of the unsaturated transfer process by which water moves down from that part of the Spokane River which is losing water to the aquifer have been made along the river's edge in the State Line vicinity. When a shaft is put down beside the river's edge, it proceeds in moist unsaturated sand and gravel; and, when a short adit section is then dug laterally to be in a position vertically beyond the river's edge, a drop by drop fall of water can be observed from the unsaturated sand at the crown of the adit.

The drop from the crown falls on the sand and gravel floor of the adit and disappears without evidence of wetness or saturation. Though no formal record of this hydrologic mechanism has been made in the Spokane Valley, by lysimeter or such measurements, the process is well known in hydrologic science. Also well known is the partial sealing effect that can build up at the surface as sediment carrying water infiltrates an unsaturated permeable granular subsurface. This phenomenon must occur in the Post Falls - Greenacres reach of the Spokane River and account for the river's ability to cross that permeable reach during periods of low flow.

Some spot tests on the moisture content of the sand and gravel material between the surface and the water table in Spokane Valley were made and results published by Phillips et al (1962), Crosby et al (1968), Crosby et al (1970) and Crosby et al (1971). These tests indicated that a moisture deficiency below field capacity existed at the time and place of sampling, including areas directly below drain fields of septic tanks. Crosby et al concluded that water does not move vertically down at the sites tested; and, consequently, would not do so from precipitation or other such surface or near surface additions of water. However, their data shows that some samples, particularly those containing some fine-grained materials do hold water at or above field capacity (Crosby et al 1971). In accordance with the rules of capillary movement of water in the unsaturated zone, it is probable that

their near-surface moisture moves down along devious subvertical paths formed by the finer grained materials which have greater capillary tension. This unsaturated transfer, by materials at field capacity, would form but a small part of the vertical column below recharge points and would be difficult to identify in the vertical drill holes used by Phillips et al (1962) and Crosby et al (1968, 1970, 1971). Some of their data show that no identifiable buildup of chemical residues occurs at the waste water disposals, a situation indicating that the downward transfer of the water and solutes along capillary-preferred routes is more likely than their conclusion that it (and the area's precipitation) is stored in the upper strata and removed by evapotranspiration during the growing season.

Currently the U. S. Geological Survey (USGS) is undertaking an extensive study of this aquifer which should provide an improved quantitative understanding of the operation of this aquifer. The USGS study is not scheduled for completion until after the completion of this study. The USGS study is described as follows, quoted from a release by USGS:

> "The objective of the study is to accurately determine the hydraulic characteristics of the aquifer, including its geometry (especially in the primary recharge of discharge areas). A digital model of the flow system that will be developed to provide a basis for guiding a basic model upon which a water-quality model may be superimposed at a later date to develop an understanding of the possible effects of various water-disposal land-use practices. The model will be developed to simulate the hydraulic response of this aquifer from the state line to the terminus of the gravel aquifer near Long Lake.
>
> Emphasis in data collection will be on: (1) Drilling and geophysical surveys to determine aquifer geometry at the Washington-Idaho border and in the areas north and west of the

City of Spokane; (2) development of water level distribution in, and pumpage from the aquifer; (3) determination of inflow from adjacent highlands; (4) determination of T and S values from pumping tests, especially in the area of the state line and northwest of Spokane; (5) determination of the hydraulic connection between surface and ground waters".

Use of Groundwater

Withdrawals from the primary aquifer are developed in other sections of this report, results of which are summarized below:

Use Category	Annual Withdrawal Acre Feet
Domestic	90,000
Industrial	17,000
Agricultural and non-agricultural irrigation	22,000
	129,000

The annual withdrawal is equal to an average rate of 178 cfs which is about one-fifth of the 1000 cfs estimated to percolate westward into the aquifer from Idaho. The domestic component of use includes a significant part that is for domestic landscape irrigation. The peak rate of summer withdrawal caused by the total of all irrigation peaks superimposed on the year around components of domestic and industrial use is of the order 400 cfs which is 40 percent of the estimate average aquifer inflow.

Of the total average groundwater withdrawal of 129,000 acre feet per year, only that part which finds its way to the City of Spokane sewer system is diverted to surface water. The estimated annual discharge of the City of Spokane sewage treatment plant, exclusive of storm

drainage and infiltration is 35 cfs or 25,000 acre feet per year. The remaining 104,000 acre feet are used (1) as domestic water supply in areas having drain field disposal of their wastes, (2) homeowner and public agency landscape irrigation and (3) agricultural use. All of these waters are returned to the surface of the aquifer. The extent to which any or all of these surface applied waters reach and recharge the aquifer is unknwon.

Interchange with Surface Waters

It has been shown above that approximately 1000 cfs of groundwater enters the study area at the interstate boundary and percolates westward through the main gravel aquifer of the Spokane Valley. It has also been shown that at present an annual average rate of 178 cfs is withdrawn from the aquifer for domestic, irrigation and industrial use of which 35 cfs is discharged to surface water and the remainder is returned to the surface of the aquifer for agricultural or landscape irrigation or through drainfield disposal of wastewaters. An unknown portion of that returned to the surface again reaches groundwater. It has long been suspected that the fate of the groundwater crossing the boundary, other than that withdrawn by man, is to be returned to surface waters by natural interchange.

In 1948 a study was undertaken by the U. S. Geological Survey in cooperation with the Bureau of Reclamation to obtain a better understanding of the interchange mechanism between the groundwater and surface waters of the Spokane and Little Spokane Rivers. The approach taken was to establish additional gaging stations on these rivers to determine by

difference the gain or loss from and to groundwater. This study and results are reported by Broom (1951).

Although high flows during part of the year tend to mask the differentials which at that season are of the same order as expected gaging accuracy, the measurements of gain or loss from the Spokane and Little Spokane Rivers give the best available approximation of the interchange process and the transmissive capability of the aquifer. Except for a few springs above the level of the Little Spokane River near Dartford and a few small springs along the banks of the Spokane River, the groundwater discharges rather inconspicuously in the gaining reaches of the Spokane River and Little Spokane River. Only in certain parts of gaining reaches of the river can water be seen entering in sandboil fashion, and this groundwater discharge is evident only during lower stages of the river. The reaches of the river to which groundwater discharge takes place are those where the water table stands above the level of the river. Because the levels of both the river and the water table fluctuate as much as several tens of feet each year, the limits of the gaining reaches of the river change with the respective levels of these interacting water bodies. The water table fluctuates through an annual recharge and discharge cycle and in reponse to changes in river level as well as in response to other cyclic and noncyclic recharge and discharge events, including changes in response to long term multi-year variations in precipitation. Annual cyclic changes of 10 to 20 ft. in the level of the water table in wells have been described by Piper and

La Rocque (1944). The lowest general levels of the water talbe were reached in 1931 during a low point in the long range precipitation cycle.

Broom (1951) was able to reach the following conclusions based on measurements for the water year 1950:

	cfs					
	Gain by River			Loss by River		
River Reach	Aver	Max	Min	Aver	Max	Min
Spokane River						
1. Post Falls to Greenacres		529		78	757	
2. Greenacres to Trent Bridge	370	1140	39			
3. Trent Br. to Green St.	566	1650			12	
4. Green St. to Hangman Cr.		216		39	428	
5. Hangman Cr. to Seven Mile	126	427			184	
6. Seven Mile to Nine Mile	21				1028	
7. Nine Mile to Long Lake	157				1422	
Little Spokane River						
8. Dartford to Mouth	218	250		—		
TOTALS	1458			117		

Note the large variation throughout one year, not only in magnitude, but in direction. The location having the most consistent direction of flow and quantity is the Little Spokane.

The general conclusion indicated by the average direction of flow in Bloom's investigation is confirmed by the water table contours developed

in this study. The reaches wherein the river recharges the groundwater and others where it receives discharge from the groundwater are evident from a comparison of the levels of the river and water table. For example, in the section from Greenacres to Green Street, where Broom shows the largest consistent gains by the river, the water table is seen to stand normally a few feet above the river level. However, rapid rises in the river level result in correlative rises in the groundwater near the river. These recharge waves in the water table are well shown by graphs such as Plate 6 of Piper and La Rocque (1944). The discharge from riverbank wells of the City of Spokane at Parkwater is commonly chlorinated during strong recharging of the groundwater by these episodes of rapidly rising river level.

Another aspect of the aquifer that is demonstrated by the water table contours developed in this study is the relative permeability. More permeable parts of the aquifer are indicated by flatter gradients; and less permeable parts of the aquifer are indicated by steeper gradients.

In order to make a water balance on the groundwater regime it is necessary to estimate recharges to the surface of the aquifer within the study area. Rainfall on the 90 square miles of valley floor itself creates a potential contribution of 26 cfs if 4 inches (about one fourth of the annual) are assumed to percolate its highly permeable surface. Rainfall on the 80 square miles of surrounding uplands could contribute another 15 cfs. As pointed out above, irrigation and drainfield

create potential for some fraction of 178-35 = 123 cfs to contribute. If 15 percent of the latter is assumed to reach groundwater, the total potential surface recharge is 26 plus 15 plus 18 = 59 cfs. These highly doubtful items are seen to make up only a small part of the water balance. Thus a crude water balance would be as follows:

	Average Addition to Groundwater cfs	Average Deletions from Groundwater cfs
Entering the study area from Idaho	1000	
Recharge from the Spokane R.	117	
Recharge from Surface	59	
Discharges to the Spokane R.		1240
" " " Little Spokane R.		218
Pumpage		178
	1176	1636

It is evident that either the Pluhowski and Thomas (1968) estimate of the inflow is too low or that the Broom (1951) estimate of river gains from groundwater is too high. A check made for other water years indicates that the years measured by Broom may be above average. On the other hand, Pluhowski and Thomas were working from methods inherently less reliable than Broom. Nevertheless, despite these inconsistencies, the general size of the groundwater stream and its interchange with the river appear to be confirmed by the water balance.

TABLE I

HYDRAULIC PROPERTIES OF THE SPOKANE VALLEY AQUIFER

	East of Idaho State Line	Hillyard Trough
Saturated section (sq. ft.)	3.82×10^6	2.10×10^6
Width (ft.)	13,400	14,000
Average Thickness (ft.)	285	150
Estimated Average Flow (cfs)	1,000	200
Effective porosity (estimated)	.25	.20
Velocity (ft./day)	90.5	41.1
Water Table Gradient (ft./mile)	10	26
Permeability (gals/day/sq.ft.)	89,143	12,600
(cm/sec)	4.2	0.6
Transmissivity (gals/day/ft.)	25.4×10^6	1.9×10^6

17

LIST OF REFERENCES

Baker, V.R., 1973, Paleohydrology and Sedimentology of Lake Missoula Flooding in Eastern Washington, Geol. Soc. Amer. Special Paper 144.

Becraft, G.E., and Weis, P.L., 1963, Geology and Mineral Deposits of the Turtle Lake Quadrangle, Washington, U.S. Geological Survey Bull. 1131.

Bretz, J.H., 1923, "The Channeled Scablands of the Columbia Plateau", Jour. Geology, v. 31, no. 8, p. 617-649.

Bretz, J. H., 1969, "The Lake Missoula Floods and the Channeled Scabland", Jour. Geology, v. 77, no. 5, p. 505-543.

Broom, H.C., 1951, Gaging Station Records in Spokane River Basin, Washington ... for Water Years 1948 to 1950, U.S. Geological Survey

Cline, D. R., 1969, Groundwater Resources and Related Geology North-Central Spokane and Southeastern Stevens Counties of Washington, Washington Department Water Resources, Water Supply Bull. 27.

Crosby, J.W. III, et al., 1968, "Migration of Pollutants in a Glacial Outwash Environment", Water Resources Research, v. 4, no. 5, p. 1095-1114.

Crosby, J.W. III, Johnstone, D.L., and Fenton, R.L., 1970, "Migration of Pollutants in a Glacial Outwash Environment, Part III", Water Resources Research, v. 7, no. 1, p. 204-208.

Crosby, J.W., Johnstone, D.L., and Fenton, R.L., 1971, "Migration of Pollutants in a Glacial Outwash Environment, Part III", Water Resources Research, v. 7, no. 3, p. 713 - 720.

Donaldson, N.C., and Giese, L.D., 1968, Soil Survey of Spokane County, Washington, United States Department of Agriculture.

Flint, R.F., 1936, "Stratified draft and deglaciation of Eastern Washington, Geol. Soc. America Bull., v. 47, no. 12, p. 1849-1884.

Fosdick, E.R., 1931, A Study of Ground Water in the Spokane and Rathdrum Valleys, Report to the Washington Water Power Company, Engineering Department, Spokane, Wash.

Frink, J.W., 1962, Spokane Valley Project - Geology and Groundwater Factors Controlling Design and Construction of Water Wells, U.S. Bureau of Reclamation open file report.

Griggs, A. B., 1966, Reconnaissance Geologic Map of the West Half of the Spokane Quadrangle, Washington and Idaho, Miscellaneous Geologic Investigations, Map I-464, U. S. Geological Survey.

McDonald, C. C., and Broom, H. C., 1951, Analysis of Increments of Discharge in Spokane River, Post Falls, Idaho to Long Lake Washington, U. S. Geological Survey open file report.

Nace, R. L., and Fader, S. W., 1950, Records of the Wells on Rathdrum Prairie, Bonner and Kootenai Counties, Northern Idaho, U. S. Geological Survey open file report.

Newcomb, R. C., 1933, Underground Water of the Upper Spokane River Valley, Washington State College Bachelor's thesis.

Newcomb, R. C., 1959, "Some Preliminary Notes on Groundwater in the Columbia River Basalt", Northwest Science, v. 33, no. 1, Feb. 1959, p. 1-18.

Newcomb, R. C., et al; 1953, Seismic Cross Sections Across the Spokane River Valley and the Hillyard Trough, Idaho and Washington, U. S. Geological Survey open file report.

Pardee, J. T., and Bryan, Kirk, 1926, Geology of the Latah Formation in Relation to the Lavas of the Columbia Plateau near Spokane, Washington, U. S. Geological Survey Prof. Paper 140-A.

Phillips, R. A., et al; 1962, Spokane Valley Groundwater Pollution Study, Washington State University Research Report No. 6219-123.

Piper, A. M., and La Rocque, G. A. Jr., 1944, Water-Table Fluctuations in the Spokane Valley and Contiguous Area, Washington-Idaho, U. S. Geological Survey Water Supply Paper 889-B.

Pluhowski, E. J. and Thomas, C. A., 1968, A Water Balance Equation for the Rathdrum Prairie Groundwater Reservoir, Near Spokane, Washington, U. S. Geological Survey Prof. Paper 600-D, p. D75-D78.

Richmond, G. M., et al; 1965, Glacial Lake Missoula, its Catastrophic Flood.... and the Loesses and Soils of the Columbia Plateau, Pt. F in Guidebook for Field Conference E, Northern and Middle Rocky Mountains--Internat. Assoc. Quaternary Research, 7th Cong., Lincoln, Nebraska, Nebraska Acad. Science, p. 68-89.

Rieber, Frank Jr., and Turner, D. S., 1963, Drilling and Completion Report of the Hillyard Trough Well No. 1, Spokane County, Washington, Ball Associates, Ltd., report to Washington Water Power Co.

Rigg, G. B., 1958, Peat Resources of Washington, Bulletin No. 44, Washington (State) Division of Mines and Geology.

Scheid, V. E., Hosterman, J. W., and Sohn, I. G., 1954, Excelsior High-Alumina Clay Deposit, Spokane County, Washington, U. S. Geological Survey open file report.

Weigle, J. M., and Mundorff, M. J., 1952, Records of Wells, Water Levels and Quality of Groundwater in Spokane Valley, Spokane County, Washington, U. S. Geological Survey open file report.

Weis, P. L., 1968, Geologic Map of the Greenacres Quadrangle, Washington and Idaho, Geologic Quadrangle Map GQ-734, U. S. Geological Survey.

Weis, P. L., and Richmond, G. M., 1965, "Maximum Extent of Late Pleistocene Cordilleran Glaciation in Northeastern Washington and Northern Idaho", Professional Paper 525-C, Geological Survey Research 1965, U. S. Geological Survey, p. C128-C132.

APPENDIX I

Representative Water Wells in the Principal Aquifer of the Spokane Valley in Washington and adjoining portions in Idaho.

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remarks
					Material	Depth (Ft.)	Depth	Date		
T. 25 N., R. 42 E.										
3H1 (1)	City of Spokane	125	24	125	Gravel	93-125	26.5	4-10-51	1679.2	(2)(3)
11E1	U.S.A. (Air base)	87			Sd & gr.	40-79	28 (4)	11-28-41	1707.2	
11R1	L. Vogel	46	120		Do.	32-46	15.9	4-24-51	1710	
23B1	City of Spokane	59	48	45	Do.	34-59	34.4	4-10-51	1798.5	
T. 25 N., R. 43 E.										
2Q1	V. Sabin	85	40	85			68.1	5-8-51	1951.7	
4B1	City of Spokane	212	60	212	Sd & gr.	198-212	183	4-10-51	2047.2	
8A1	Do.	124	216	120	Do.	50-124	78.9	4-25-51	1946.0	
8H1	Brewers Lumber Co.	86	24-12	86			74.0	4-23-51	1772	
9G1	C. Perry	32	36	32	Sd & gr.	20-36	19.1	5-8-51	1891.7	
9H3	L. Reed	23	30				12.7	5-12-51	1886.2	
9M1	D. Dawson	23	30	23			20.4	5-10-51	1892.2	

footnote explanations at end

APPENDIX I (continued)

Well Number	Owner	Depth (Ft)	Dia. (In)	Casing depth (Ft.)	Water-Bearing Zone		Water level		Alt. top Casing	Remarks
					Material	Depth (Ft.)	Depth	Date		
T. 25 N., R. 43 E., continued										
10F1	A. Joireman	71	30				61.9	5-5-51	1938.1	
10J1	T. Balderson	20	48	20			8.9	5-8-51	1888.3	
10L1	S. Allen	17	36	17			5.5	do	1882.9	
10R1	Swift & Co.	69	96		Gravel		61.7	6-23-42	1941.4	
11B1	C. Neighbors	72	6	72			45.3	5-8-51	1929.1	
11C1	H. Bandschue	63	6	63			50	4-24-51	1948	
11E1	Nalley Pickle Co.	77	36	77	Gravel	55-84	55.8	do	1937.9	
11G3	City of Spokane	42	292	39	do	23-42	23.9	6-14-51	1901.8	One of 5 wells in area.
11G6	Do	64	30	62	do	54-64	54.8	6-19-51	1937.0	
11K1	Do	70	36-18	70			65.0	do	1945.0	
11M1	Spokane Rend. Co	13	44	13			16.5	4-26-51	1892.2	
12H1	Orchard Ave. Irrig. Co.	94	84	94	Gravel	54-94	53.6	4-15-42	1946.4	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft)	Dia. (In)	Casing depth (Ft.)	Water-bearing zone Material	Water-bearing zone Depth (Ft.)	Water level Depth	Water level Date	Alt. top Casing	Remarks
T. 25 N., R. 43 E., Continued										
12L1	J. Jones	66	30	55	Gravel	59-69	59.1	4-12-42	1948	
12N1	Spokane Elect. Steel Co.	73	6		Gr & Sd		53.4	5-24-51	1941.9	
13A1	C. Reeder	108	10	106	Gravel	57-106	57.5	11-17-51	1955	
13E1	G. Johnson	63	24		do	51-65	53.6	4-15-42	1938	
13Q1	Mrs. E. Norton	80	6				71.2	5-24-51	1960	
14G1	City of Yardley	72	96				48.2	5-11-51	1934.8	
14J1	Diamond Match Co.	59	52-96	59			46.2	do	1930	
15G1	White Pine Sash	120	12	120	Gravel	64-118	64.7	do	1945.9	
16J1	[illegible] Lumb.	57	54				51.0	4-17-42	1923.1	
17D1	New Method Laund.	52	48-30	52			47.6	6-19-51	[illegible]	
17E1	G. Harris	35	84-30	35			26.8	4-23-51	1893.4	
21B1	Troy Laundry	50	48-72				37.0	5-10-51	1915.6	(5)
22F1	City of Spokane	77	288	77	Gravel	37-77	37.9	4-10-51	1915.8	
23C1	Carnhope Irrig. Dist. No. 7	79	78-60	79	do	58-77	58.6	4-15-42	1937.6	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone: Material	Water-bearing zone: Depth (Ft.)	Water level: Depth	Water level: Date	Alt. top casing	Remarks
T. 25N., R. 43E., Continued										
24G1	East Spokane Water Dist. No1	144	48				137.0	4-16-42	2022.6	
T. 25N., R. 44E.										
1K1	W. Steinke	82	50	82	Gravel	76-82	76.1	4-7-42	2019	
2B1	Trentwood Irrig. Dist.	127	72		Sd & gr		93.2	6-19-51	2034.9	
2Q1	Kaiser Alumin. & Chem. Corp.	129	12		Gravel	78-129	78.7	3-23-42	2012	
3E1	C. Johnson	44	24	44			38.4	4-6-42	1956	
4J1	Spokane Portland Cement Co.	90	96	90			61.5	5-25-51	1947.4	(5)
4K1	Spokane Sand & Gravel Co.	14	120-72	14	Sd & gr		1.7	do	1911.7	
5N1	Inland Empire Paper Co.	93	6	93	Gravel		57.2	4-14-42	1963	
6A1	Pasadena Park Water Co.	104	84-63	104	do	84-104	84.2	4-15-42	1982	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone Material	Water-bearing zone Depth (Ft.)	Water level Depth	Water level Date	Alt. top casing	Remarks
T. 25 N., R. 44 E., Continued										
7D1	E. Hardie	90	6	90	Gravel	59-90	59.7	11-19-51	1950	
7J1	R. Meyers	94	6				70.8	5-25-51	1976.4	
8G1	Do	57					51.0	4-14-42	1955	
8N1	Modern Electric Water Co.	137	72	100	Gravel	103-137	103.3	4-9-42	2012.7	
9J2	Pine Croft Inn Co.	47	120				27.8	5-28-51	1951.9	
9R1	J. Stitz	52	48		Gravel	48-52	48.6	4-8-42	1968	
10Q1	J. Mossell	62	36	62	Sd & gr	52-62	52.6	1-22-38	19[illegible]4.0	
10Q2	Mrs. Cruikshank	62	36	61			59.7	3-21-28	1988.7	
10R1	------	62	5.5	62			45.4	4-8-42	1976	
11J1	Kaiser Alumin. & Chem. Corp.	55	28				45.8	4-7-42	1991	
11N1	U.S. Bur. Reclam.	147	16	116	Gr & sd	116-141	61	7-29-64	1990.0	BR site.
12Q1	Millwood Paper Co.	56	24	56			49.1	6-26-51	1989	

* Note to reviewers. Bureau of Reclamation holds title to these wells; [illegible] Irrigation District does not.

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remarks
					Material	Depth	Depth	Date		
T. 25 N., R. 44 E. - Continued										
13M1	Vera Irrig. Dist. No. 15	125	72	90	Gravel	98-125	98.8	6-12-51	2033.4	
							89.4	3-20-28	2025.4	
14P2	W. Shaw	96	48							
15E1	Modern Electric Water Co.	147	84		Sd & gr		129.4	6-11-51	2051.9	
15J1	Vera Land Water Co.	142	72-6	120	Gravel	119-142	119.7	6-12-51	2055.5	
16E1	Modern Electric Water Co.	128	84		do		92.3	6-11-51	2014.9	
17M1	Do	114	72		do		89.9	do	1999	
18M1	F. Lawhead	79	24		do	67-79	67.2	6-6-51	1964.0	
19D1	Edgecliff Sanitar.	88	60-30	88	Sd & gr		74.5	6-19-51	1969.2	
20A1	S. Stauser	103	6		Gravel		73.6	4-10-42	1982	
20K1	L. Oestreicher	127	30		Sd & gr	112-127	112.4	5-29-51	2028	
21J1	Modern Electric Water Co.	117	84	117	do		99.5	6-11-51	2021.3	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remarks
					Material	Depth (Ft.)	Depth	Date		
T. 25 N., R. 44 E., Continued										
21N1	Model Water & Light Co.	181	84	157	Sd, coarse	165-181	165.3	6-27-51	2055.0	
22H1	Vera Irrig. Co.	105	72		Sd & gr		80.5	6-12-51	2016.5	
22N1	Modern Electric Water Co.	163	78	135	Gravel	135-163	135.7	6-11-51	2065.0	
22R1	Vera Irrig. Dist. No. 15	180	72-6	180	do	146-180	146.4	6-12-51	2083.5	
							84.7	6-21-51	2016.4	
23D1	L. Lewis	97	48-18							
24A1	R. Danklefs	92	4	92	Gravel	90-92	90.2	3-26-42	2032	
26D1	Vera Irrig. Dist. No. 15	176	72	152	do	148-172	148.1	6-12-51	2054	
26L1	Do	166	72	166	Sd, coarse	126-166	126.8	do	2066.0	
28M1	E. Sprow	88	36				73.0	5-29-51	2000	
29B1	M. Lettenmeier	122	6		Sand	108-122	108.4	do	2040	
33D1	C. Taylor	113	5				103.9	6-27-51	2025	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone: Material	Water-bearing zone: Depth (Ft.)	Water level: Depth	Water level: Date	Alt. top casing	Remarks
T. 25 N., R. 44 E., Continued										
33Q2	Hathaway	82	30				72.9	6-27-51	2012	
34J1	G. Tobert	134	5		Sand	95-100	96.0	4-9-42	2032	
34K1	G. Hawkins	100	6	100	do	94-100	94	do	2030	
T. 25 N., R. 45 E.										
1A1	C. Steffensmier	98	4				64.9	6-26-51	2047	
2G2	U.S. Bur. Reclam.	235	16-14	228	Gravel	168-228	104.0	12-29-64	2066.1	BR site 9A
2J1	A. Griner	57	36	57	do		49.0	6-26-51	2033	
3A1	Hellbaum	118	6				88.3	6-14-51	2059	
3F1	U.S. Bur. Reclam.	220	20-16	210	Gravel	95-220	95.2	8-17-64	2052.2	BR site 8A
3P1	F. Dilley	116	6	116			79.2	11-17-51	2045	
4C2	U.S. Bur. Reclam.	225	20-16	214	Gravel	106-225	106.2	10-8-64	2057.8	BR site 6A
4E1	O. Darrah	130	6	130			97.7	11-13-51	2060	
4N1	B. Eddy	86					77.9	3-27-42	2029	
4P1	S. Bergerson	111	6				71.7	11-7-51	2035	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remarks
					Material	Depth (Ft.)	Depth	Date		
T. 25 N., R. 45 E., Continued										
5H1	F. Shinn	137	12				87.8	6-14-51	2060	
5L1	Inland Paper Co.	80	24	80			62.9	do	2026	
6H1	W. Fenman	93	30		Gravel	86-93	86.7	3-26-42	2033	
7A1	U.S. Bur. Reclam.	195	20-16	185		138-185	70.9	8-14-64	2021.9	BR site.
7G2	G. Carrier	96	48		Gravel	62-96	62.1	6-26-51	2015	
8R1	R. Rudebaugh	111	60-6	111	do		87.6	6-13-51	2053.2	
10C1	W. Lielman	67	36		Sd & gr		50.5	do	2019.2	
10F1	G. Neyland	85	36		Gravel		61.0	do	2028	
10N1	J. Morris	126	6		Sand		97.1	do	2060	
11B1	A. Winnestorfer	86	6	90			58.1	6-26-51	2040	
14M1		175	4				161.6	3-19-42	2115	
16C1	Inland Empire Paper Co.	129	96	128	Sd & gr		94.9	6-19-51	2055.6	
17D1	U.S. Bur. Reclam.	230	20-16	207	Gravel	87-230	87.9	11-2-64	2035.3	BR site

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone: Material	Water-bearing zone: Depth (Ft.)	Water level: Depth	Water level: Date	Alt. top casing	Remarks
T. 25 N., R. 45 E., Continued										
17E1	Community Service Co.	104	72		Gr & sd	92-104	92.8	3-25-42	2036	
17P1	U.S. Bur. Reclam.	207	16-14	197	Gravel	94-197	94.2	8-18-64	2044.6	BR site 3A.
17R1	R. Jeffers	131	6				112.1	6-13-51	2076	
18A1	O. Nilson	98	72-30		Sd & gr	90-98	90.1	1-21-38	2036.5	
18Q1	T. MacDonald	99	30	99	Gravel	95-99	95.3	3-25-42	2041	
18R1	U.S. Bur. Reclam.	230	20-16	217	Gravel	88-217	88.0	7-16-64	2091.5	BR site 2A
20M1	V. Hepton	134	8				117.1	6-8-51	2085	
T. 25 N., R. 46 E.										
6F1	Concrete Inds.	80	6	80	Gravel	59-80	59.0	11-19-51	2090	
T. 26 N., R. 42 E.										
3E1	J. Willis	12	36				6.4	5-19-51	1555	
4L1	A. Rettig	9	12				6.6	5-17-51	1550	
5F1	W. Melcher	12	48				4.4	do.	1545	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone Material	Water-bearing zone Depth (Ft.)	Water level Depth	Water level Date	Alt. top casing	Remark
T. 26 N., R. 42 E., Continued										
5L1	W. Norman	16	12-24				8.9	5-17-51	1548	
6K1	Wash. Water Power Co.	101	18				77.2	5-16-51	1605	
7G1	E. Covington	45	12				29	do	1625	
9N1	R. Fellow	58	12				13.4	do	1630	
5K1	M. Allen	23	36				16.4	5-17-51	[illegible]	
17A1	C. Swan	204	6				50	5-16-51	1655	
20A1	G. McLellan	42	32	42			31.1	12-12-41	1632	
21C1	H. Wilson	87	6	87			56.8	5-17-51	1665	
21D1	W. Dealy	46	30-6		Gravel		23.9	6-16-51	1638	
21E1	Mrs J. Ray	34	60	34	do		16.3	do	1627	
28D1	U.S. Govt.	90	60	90			75.8	12-12-41	1682	

(6)

METROPOLITAN SPOKANE REGION WATER RESOURCES STUDY.

APPENDIX B.

GEOLOGY AND GROUNDWATER

(12) 325p.

(11) JANUARY 1976

Department of the Army
Corps of Engineers, Seattle District

Kennedy-Tudor Consulting Engineers

KENNEDY TUDOR

410075

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remarks
					Material	Depth (Ft.)	Depth	Date		
T. 26 N., R. 43 E.										
1D1	O. Humphries	112	24	112			104.2	11-14-62	1870	Cline, 1969
2A1	Do	150	6				100	1957	1870	
4P1	Mesa School Dist.	146	12	126	Sand		85	7-17-64	1830	Cline, 1969
4Q1	H. Wood	26	42		do	22-26	22.8	4-27-42	1841	
6G1	Riville Water Co.	30	12	30	Gravel	18-30	8.3	3-30-65	1580	Cline, 1969
7P1	Wash. Water Power Co.	126	16	93	Sand	93-114	43.4	5-7-63	1780	do.
							74.4	6-19-51	1775.0	
7Q1	Marr Estate	88	72	88	Gravel	74-88	40	10- -63	1775	Cline, 1969.
8B1	M. Deshler	54	6	54	Sand		55	9- -63	1790	Do.
8B2	Meader	63	10		Sd & Gr		38		1765	Do.
8B4	Wash. Water Power Co.	90	12	90	Sand	59-30				
8F1	E. Billberg	44	40	40	Sand	41-44	41.0	4-18-42	1783	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone: Material	Water-bearing zone: Depth (Ft.)	Water level: Depth	Water level: Date	Alt. top casing	Remarks
T. 26 N., R. 43 E., Continued										
10K1	Wash. Water Power Co.	106	48-22	106	Sd & gr		88.8	3-29-65	1910	Cline, 19
10Q1	W. Whipps	130	6	124	do	112-130	112	5- -41	1909	
15C1		135	do		do		Dry	1941	1910	
16C1	Kaiser Alumin. & Chem. Corp.	280	16-8	277	do		162.3	4-17-51	1938	
16D1	Do	247	8-6	247	do		159.9	4-12-51	1937	
16D3	Do	286	20-16	286	do		159.5	5-17-51	1938	
16F2	Do	268	24-18	238	do	238-268	157	4-25-55	1940	Cline, 19
16G1	Bonneville Power Admin.	556	10	346	do		154	11-24-42	1942.3	Top Latah at 295
17B1	Nelson Landscap. Service	224	8-6	224	do	199-220	173.5	5-1-64	1940	Cline, 19
17G1	J. Miller	183	6		Sand	150-183	178.6	5-21-51	1945	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone Material	Water-bearing zone Depth (Ft.)	Water level Depth	Water level Date	Alt. top casing	Remarks
T. 26 N., R. 43 E., Continued										
17J1	El Paso Natural Gas Co.	248	6	248	Sd & gr	228-243	175.1	4-27-65	1945	Cline, 1969.
18G1	Whitworth College	200	72	140	do	160-180	160.8	12-23-41	1915	
19A1	Country Homes Estate	161	74-60		Gravel		135.0	6-19-51	1935.6	
19R1	C. Weipert	248	6		do	220-248	218	5-22-51	2050	
20D1	Whitworth Water Dist. 2, well 2	286	16	253	Sd & gr		152	6-12-62	1950	Cline, 1969
20J1	Wash. Water Power Co.	430	6	270	Sd, fine	195-215	190.3	5-2-63	2011	Do. Found top Latah Fm. at 360 ft.
20N1	Wash. Water Power Co.	238	12	238	Sd & gr		208.2	3-29-65	2040	Cline, 1969
21E1	Pac. NW Alloys	206	84	180	Sand	180-206	180.7	7-7-42	1990	
21F1	Do	163	96		do		162.6	5-1-42	1965	
22N1	Phillips Refin. Co.	216	18		do		170	5-22-51	1990	
27F1	National Pole	200	48	180	do		171.4	12-20-41	200.0	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone Material	Water-bearing zone Depth (Ft.)	Water level Depth	Water level Date	Alt. top casing	Remarks
T. 26 N., R. 43 E., Continued										
27L1	National Pole	207	96		Sd & gr	172-207	172.8	5-22-51	1995	
28D1	C. Calkins	310	30-19	310	do	210-292	197.0	10-9-64	2025	Cline, 1969
28H1	N. Spokane Irrig. Dist. 8, well 2	250	96		do		190	5-2-64	2031	Do.
28M1	C. Calkins	251	40	251	Sand	211-251	211.9	10-9-64	2051	Do.
29R1	G. Chorter	259	8	259	Gr & sd	239-259	209.5	7-16-64	2053	Do.
30G1	Holy Cross Cem.	218	60	207	Sd & gr	204-218	204.8	4-21-42	2046	
30R1	C. McCarroll	238	18	238	Sand	229-238	229.7	11-16-51	2074	
30R2	Wash. Water Power Co.	293	16	293	Sd & gr	229-293	230.4	11-16-51	2070	Cline, 196[illegible] Spok. Terrace
31H1	City of Spokane	270	96-84	270	do	225-270	225	8-13-65		Central Ave No. 1 Cline, 196[illegible]
34P1	Great Northern Ry.	240	72	240			172.9	6-19-51	2035.6	
35E1	J. McKay	140	54		Sd & gr		101.1	5-23-51	2020	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remar
					Material	Depth (Ft.)	Depth	Date		
T. 26 N., R. 44 E.										
32N1	R. Frazier	106	66				102	3-15-28	2003	
32R1	Hutton Settlement	113	72-46	113	Gr & sd	92-113	92.3	6-19-51	2001.7	
36R1	C. Sperber	158	6	140			72.2	11-19-51	2100	
T. 26 N., R. 45 E.										
13N2	E. Mellick	156	6	156	Sand		145		2130	
14K1	T. Bell	159	6				152.9	10-31-51	2195	
25D1	A. Maurer	126	6	126	Gravel		102.6	11-5-51	2090	
25E1	W. Beck	149	60		Gr & sd		116.7	do	2079.0	
26H1	V. Pintler	142	6				100	11-1-51	2077	
32J1	W. Clift	148	6				32.9	4-5-42	2105	
32P1	G. Sly	96	4	107	Gravel	92-107	92	do	2063	
33J2	T. Foy	127	2.5				99.4	3-17-28	2073	
33P1	G. Kenney	123	6	115	Gravel		99.6	6-19-51	2067	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone		Water level		Alt. top casing	Remarks
					Material	Depth (Ft.)	Depth	Date		
T. 26 N., R. 45 E., Continued										
34L2	U.S. Bur. Reclam.	238	20-16	228	Gravel	171-228	105.3	1-16-65	2067.5	BR site 7B.
34P1	R White	125	2.5				99.8	3-17-28	2077	
35F1	U.S. Bur. Reclam.	232	16-14	227	Gravel	184-227	118.0	12-9-64	2082.9	BR site 10A
35J1	C. Reeber	141	6	135			107	1- -51	2078	
36A1	M. Diener	123	5	123	Gravel	110-123	110	1942	2088	
36J1	E. Farms Dom. Water Co.	142	5	142	do		123		2090	
36N1	H. Segerstrom	129	6				98.6	6-14-51	2076	
36Q1	I. Bennett	111+	6				110.5	11-14-51	2085	
T. 26 N., R. 46 E.										
30E1	J. Beck	130	30				124.2	3-10-28	2097	
30M1	Do	140+	22-3	140	Gravel	139-140+	139.4	11-29-41	2099	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone Material	Water-bearing zone Depth (Ft.)	Water level Depth	Water level Date	Alt. top Casing	Remarks
T. 26 N., R. 46 E., Continued										
31M1	M. Arnold	147	6	147	Gravel	106-147	106.2	6-14-51	2085.9	
31M2	U.S. Bur. Reclam.	249	20-16	238	do	183-238	177.7	1-29-65	2090.5	BR Site 11A
IDAHO										
T. 50 N., R. 5 W.										
5M1	G. Anderson	119	6	119	Gravel	103-119	103.4	8-25-48	2087.4	
T. 50 N., R. 6 W.										
1L1	State Line Village	200	10	200	Gr. & sd	120-200	120.5	3-20-49	2100.6	
12K1	J. Holland	132	6	130	Gravel	87-130	87.3	5-30-48	2075.7	
13G1	M. Holland	55	18	55	do	33-55	33.8	5-30-48	2112.2	

APPENDIX I (continued)

Well Number	Owner	Depth (Ft.)	Dia. (In.)	Casing depth (Ft.)	Water-bearing zone: Material	Water-bearing zone: Depth (Ft.)	Water level: Depth	Water level: Date	Alt. top Casing	Remarks
	IDAHO - Continued									
T. 51 N., R. 5 W.										
19G1	H. Just	200	8	200	Gravel	182-200	182.9	9-6-49	2171.5	
19G2	C. Fritz	227		227	do		176.9	9-6-49	2172.3	
19P1	NP Ry	181.5	12-10	181.5	do		143.0	4-7-49	2125.2	
31E1	P. Beck	156		156	do	117-156	117.9	8-30-49	2105.4	
T. 51 N., R. 6 W.										
25J1	C. Beck	175	6	175	do	118-175	118.0	9-6-49	2107.5	

Footnotes:

(1) Numbers for wells and springs are derived from their location in the land surv grid. The township and range are followed by a hyphen and then the section. The letter refers to the 40-acre tract; the lettering is in succession west east across tiers from A in $NE\frac{1}{4}NE\frac{1}{4}$ to R in $SE\frac{1}{4}SE\frac{1}{4}$, I and O are omitte

(2) Data on wells in Washington is largely from Weigle and Murdorff, 1952; in Idaho they are fr Nace and Fader, 1950. Data on Bureau of Reclamation wells are from their unpublished rec

(2) Depth to water level is depth below land surface datum. (3) Most listed wells have recorded

(5) Indicates a few feet of pumping drawdown when water level measured.

APPENDIX II

Springs that discharge groundwater from the Principal Aquifer of the Spokane Valley.

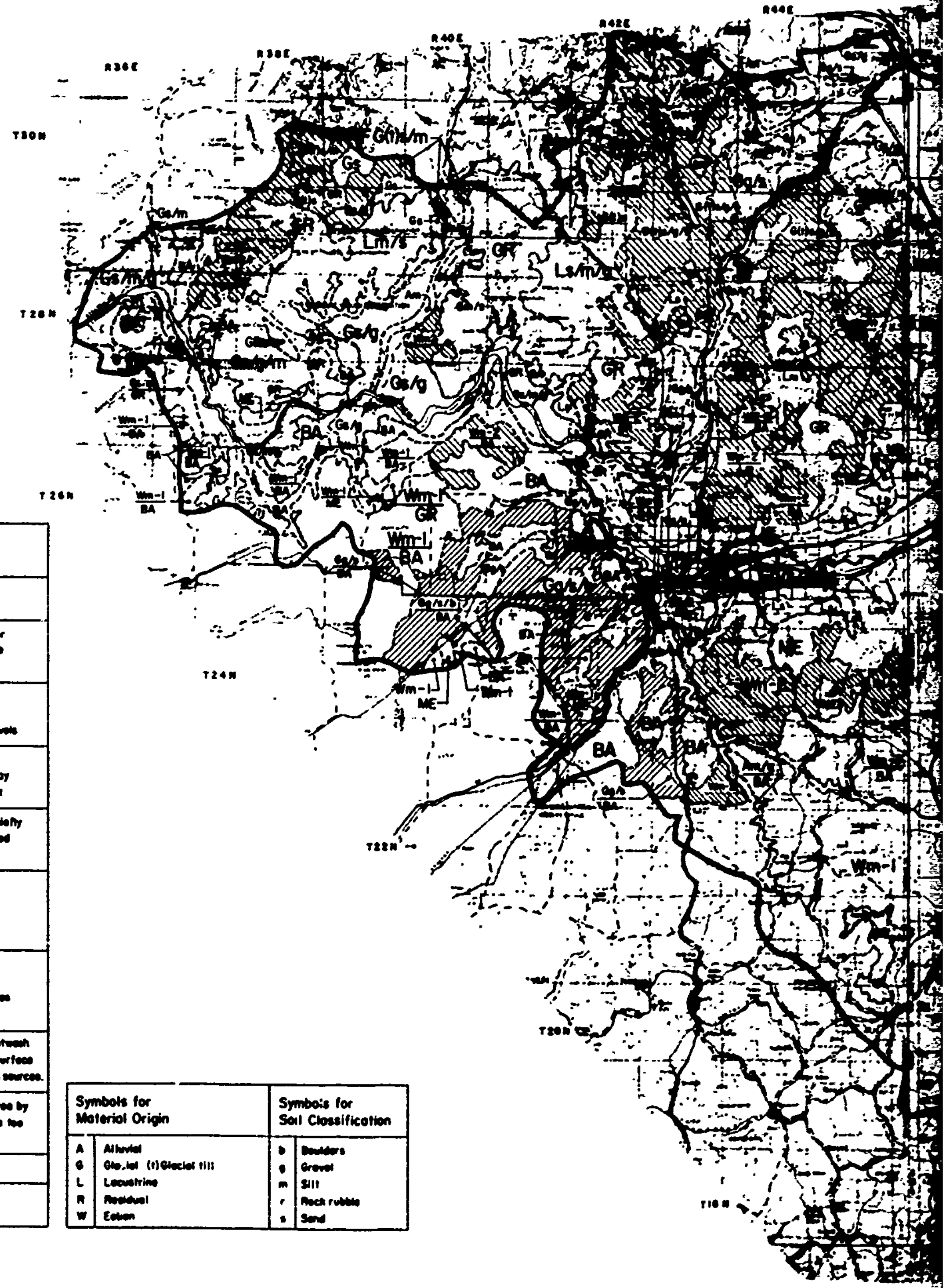
Spring Number	Owner	Altitude (Ft.)	Yield		Water-yielding material	Principal Use	Remarks
			Gpm	Date			
T. 25 N., R. 42 E.							
(1) 12M1s		1700	75	8-13-73	Sand and gravel	None	One of several flows from northern par Of Downriver Sp
12P1s		1700	25	8-13-73	do.	None	One of several of southern part o Downriver Sprs.
T. 26 N., R. 42 E.							
11J1s	Wash. Dept. Game	1590	6800	6-15-65	Gravel	Fish rearing	Hatchery Sprs. Cline, 1969.
12A1s	Spokane Country Club	1590	4000		do	Irr. Dom.	Country Club Sprs. Cline, 1969.
12L1s							
T. 26 N., R. 43E.							
5L1s	Wandermere, Inc	1665	3300	5-21-55	Sand & gravel	Fish rearing, Irr., Dom.	Wandermere Sprs. Cline, 1969

Footnotes at end of table.

APPENDIX II (continued)

Spring Number	Owner	Altitude (Ft.)	Yield Gpm	Yield Date	Water-yielding material	Use	Remarks
T. 26 N., R. 43 E., Continued							
6Q1s	Waikiki Synd.	1600	4000	1900	Gravel	None	Waikiki Sprs. Cline, 1967
7B1s	Do	1600	1500	1900	do.	Fish rearing, Dom.	Do.

(1) Numbers of springs are derived in the same manner as the numbers assigned to well (Table 1), with the addition of the letter s.



Symbol	Material	Description
Am Lm	Alluvial Silt Lake Silt	Stream bed deposits Undifferentiated silt, organic silt and peat deposits
Wm-1	Loess — Silt, Clay, Fine Sand	Loess of the Palouse Formation May contain clay and /or fine sand Primarily eolian, but includes some local lake and reworked loess deposits
Wm-2	Silt, Sand, Gravel, Boulders	Primarily reworked Palouse Formation loess. Often mixed with till, outwash, lake, or colluvial materials. Generally shallow (<20'), overlies rock or outwash gravels
Gs Ls	Sand	Predominantly sand from glacial or lacustrine origins. Often in stratified, terraced deposits. Surface areas may be reworked by wind. Occasionally contains gravel or silt
Rs	Sand, Gravel, Rubble	Unconsolidated sandy soils of the mountainous areas. Chiefly of residual and colluvial origin, but occasionally is mixed with till or outwash materials, overlies bedrock
Gg	Gravel Sand	Predominantly glacial flood and outwash deposits in valleys and on the lower slopes of flanking ridges. Generally coarse sands and fine to coarse gravel with cobbles and boulders
Gg/BR	Gravel, Sand, Boulders	Thin (< 20') outwash and flood deposits over scoured basalt surfaces west of Spokane Highly irregular in thickness. May contain silt or clay lenses. Includes areas of basalt outcrops. (Scabland deposits)
G(t)	Gravel, Sand, Rocky Till, Boulders	Ground or marginal till deposits. Generally mixed with outwash materials Shallow to moderately deep (5'-30'). Near surface zones generally mixed with silt from lacustrine or eolian sources.
BA	Basalt Rock	Basalt lava flows. Fractured. Underlain in the Spokane area by siltstone of the Latah Formation Exposures of siltstone too small to map at 1:250,000 scale
ME	Metamorphic Rock	Gneiss, schist, quartzite, etc.
GR	Granitic Rock	Intrusive rocks, including granite, quartz, monzonite, andesite, etc.

Symbols for Material Origin		Symbols for Soil Classification	
A	Alluvial	b	Boulders
G	Glacial (t) Glacial till	g	Gravel
L	Lacustrine	m	Silt
R	Residual	r	Rock rubble
W	Eolian	s	Sand

REVISIONS

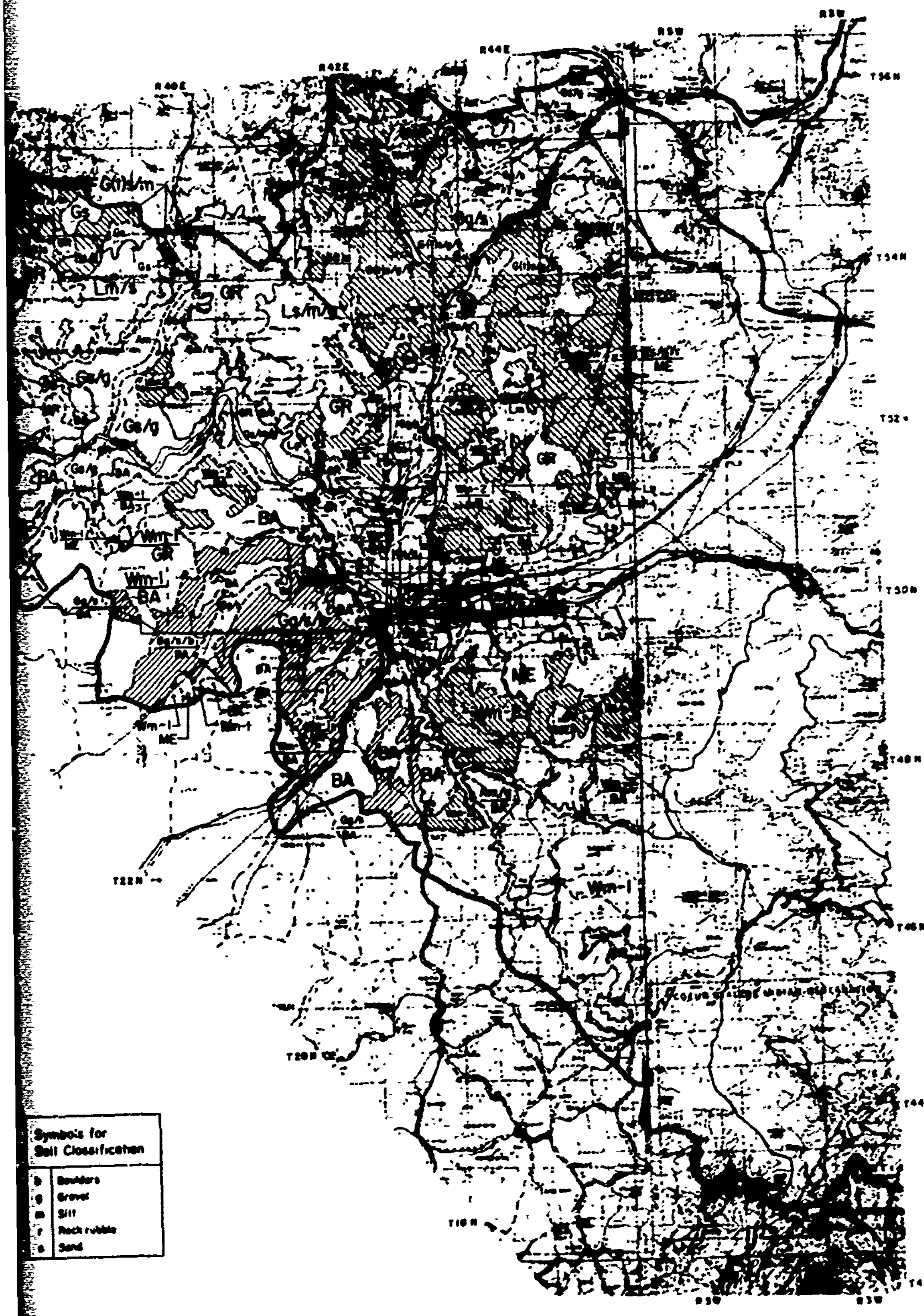
SYMBOL	DESCRIPTION	DATE	BY

MAP SOURCE PREPARED FROM USGS, UNITED STATES TOPOGRAPHIC SERIES, SANDPOINT 1958, RITZVILLE 1958, SPOKANE 1958, [illegible] 1964

5 0 5 10 15 MILES

10,000 0 10,000 20,000 30,000 70,000 FEET

GRAPHIC SCALES



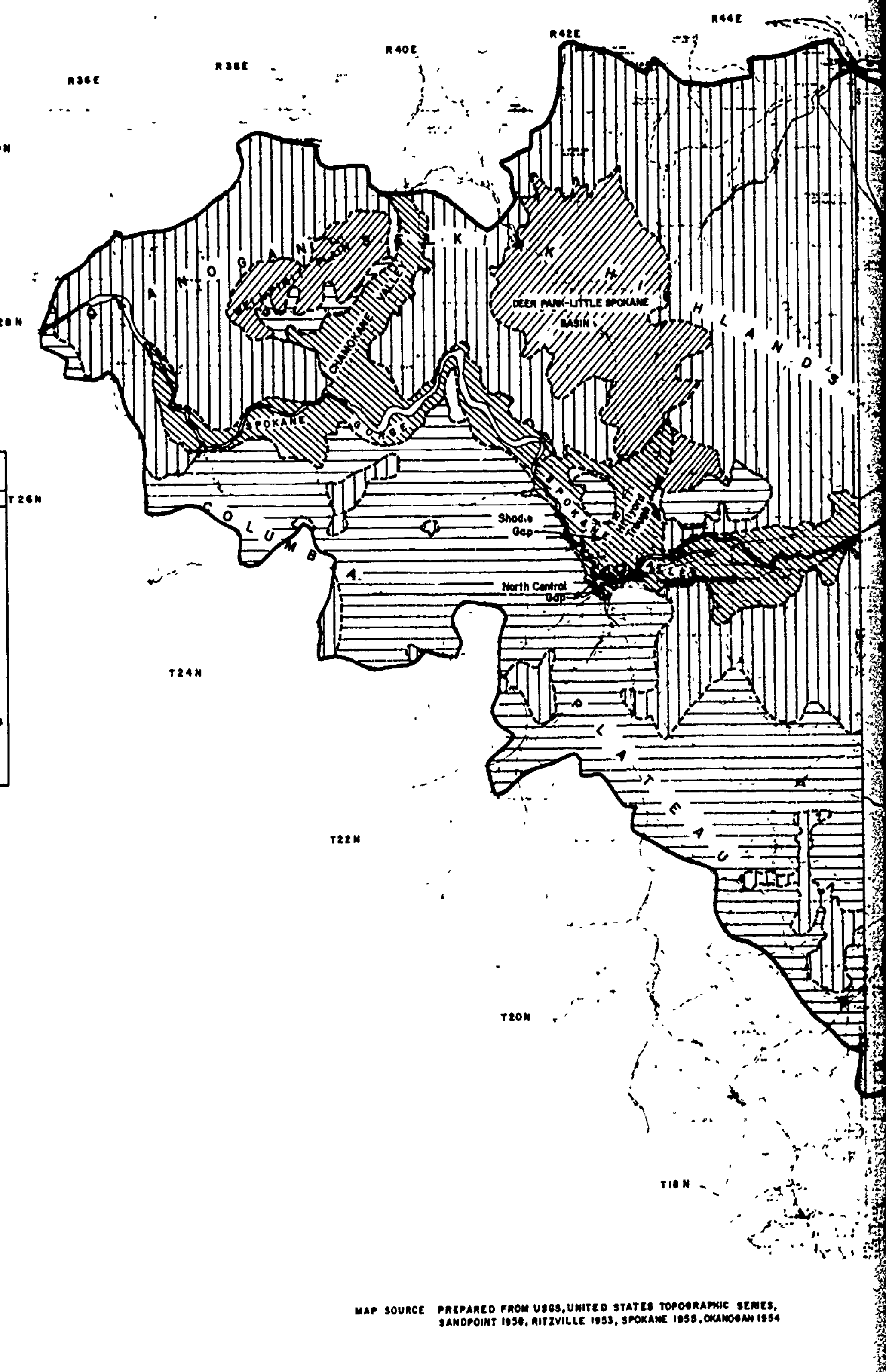
Symbols for Soil Classification	
b	Boulders
g	Gravel
m	Silt
r	Rock rubble
s	Sand

MAP SOURCE PREPARED FROM USGS, UNITED STATES TOPOGRAPHIC SERIES,
SANDPOINT 1958, RITZVILLE 1953, SPOKANE 1953, [illegible] 1954

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GEOLOGY OF THE STUDY AREA

PLATE 303-1



Symbol	Generalized Geologic Unit
	Quaternary glacial outwash Sand and gravel. Includes some post-glacial alluvium. Gravel members below the level of the water table yield large amounts of water to wells and springs
	Quaternary glacial drift Till, outwash and assorted lacustrine deposits Coarse-grained materials, in places, yield moderate amounts of water to wells and springs.
	Tertiary basalt of the Columbia River Group Layered lava flows with much interlayered shale and sandy shale of the Latah Formation, which is especially thick near the northern and eastern edges of the basalt. Layering lies essentially horizontal. The rubbly tops of some of the lava flows yield moderate amounts of water to wells Interbedded sedimentary layers yield little or no water to wells
	Pre-Tertiary rocks. Igneous intrusive and metamorphic rocks. Largely impermeable but the weathered top of granitic rocks, in places, affords small yields of water to wells and springs The regions encompassed contain many small areas underlain by patches of glacial and alluvial deposits which, in some low places, is saturated and yields small to moderate amounts of water to wells and springs.

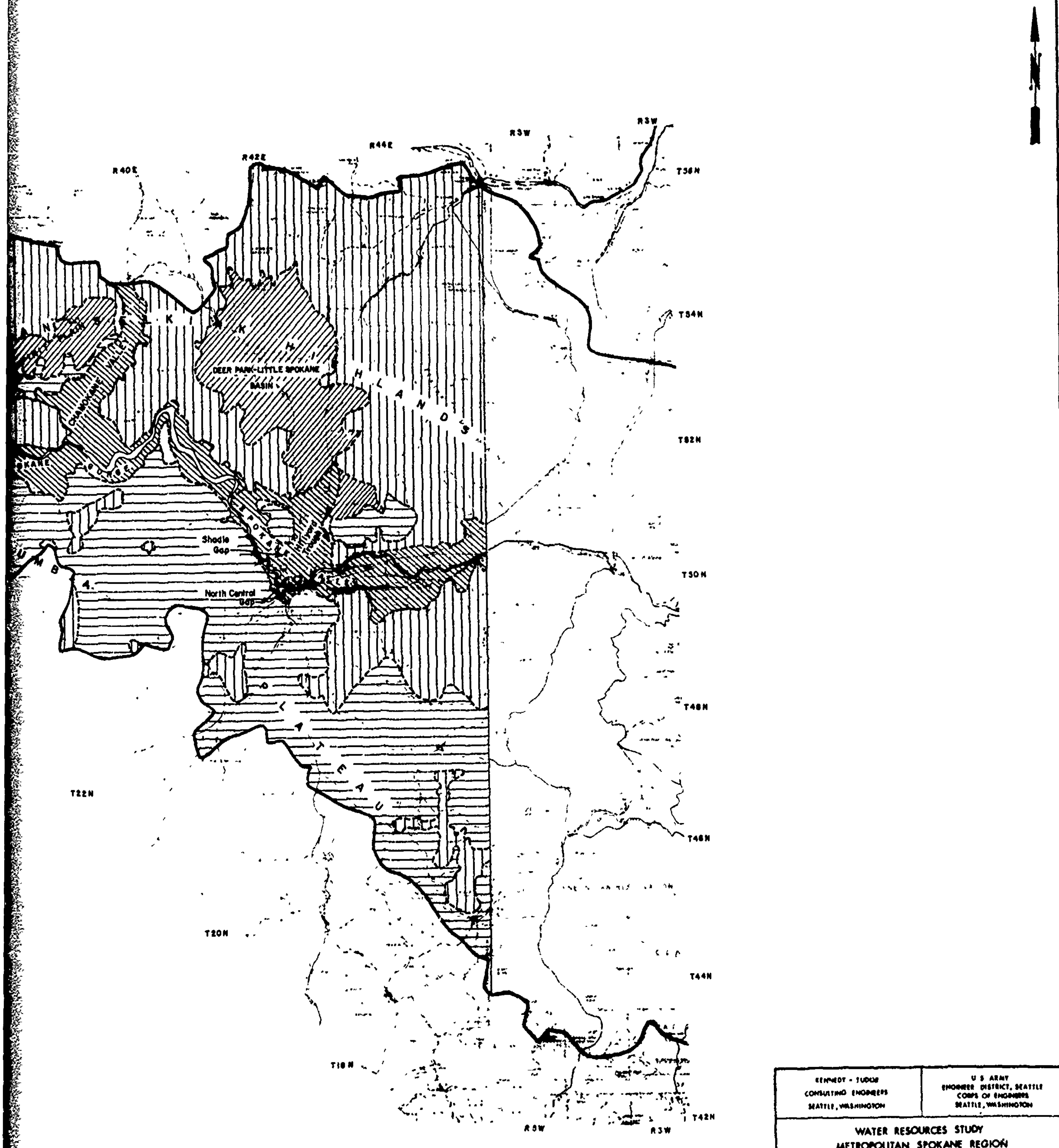
5 0 5 10 15 MILES
10,000 0 10,000 30,000 50,000 70,000 FEET

GRAPHIC SCALES

REVISIONS

SYMBOL	DESCRIPTION	DATE	BY

MAP SOURCE PREPARED FROM USGS, UNITED STATES TOPOGRAPHIC SERIES, SANDPOINT 1958, RITZVILLE 1953, SPOKANE 1955, OKANOGAN 1954



MAP SOURCE: PREPARED FROM USGS, UNITED STATES TOPOGRAPHIC SERIES; SANDPOINT 1958, RITZVILLE 1953, SPOKANE 1955, OKANOGAN 1954

KENNEDY - TUDOR CONSULTING ENGINEERS SEATTLE, WASHINGTON	U S ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER REGIONS OF THE STUDY AREA

DACW67-72-C-0096

PLATE 303-2

MATERIAL	Map Color Key	Map Unit Symbol	DESCRIPTION	DRAINAGE	FOUNDATION STABILITY	
ORGANIC		Lp	Lacustrine peat deposits Fibrous and granular organic deposits in recent shallow lake and marsh areas; grades to organic silt and silty sand near outer margins of peat bogs. Recent and late Pleistocene	Poor because of high groundwater Permeability usually high in fibrous peats, but decreases rapidly if peat is consolidated	Not suitable for building foundations Embankment fill loads may settle several inches and settlements will continue over several years.	Does not ... when dry, ...
SILT		Wm-1	Eolian silts (Palouse Formation Loess); tan to brown, includes fine sand, clay and occasional caliche zones. Pleistocene	Poor Permeability may be moderate in zones with a high concentration of root tubules Highly susceptible to erosion on slopes.	Generally adequate for light frame structures; heavy structures usually require special foundations; semi-stable particle structure may cause large settlements upon saturation. Frost susceptible.	Usually sta... failures and... subjected t... slopes will... groundwater... back or sh...
		Wm-2	Reworked Palouse Formation silts (loess); includes Recent and Pleistocene loess; occasionally mixed with sand, gravel and cobbles from residual colluvial or glacial sources; mixed with alluvial or lacustrine deposits in places and occasionally contains ice rafted erratic boulders.			
		Am Am/s Am/c	Alluvial silt. Located along streams in local decressions, and mantles flood plains; may contain sand and gravel, and may overlie glacial flood or lacustrine deposits. Recent.	Poor, clayey areas are practically impervious Generally occurs in low areas Infiltration is slow.	Not regarded as a suitable foundation soil Settlements may be excessive and irregular. Frost susceptible.	Generally ... in wet areas... areas.
		Lm Lm/s	Lacustrine silt Lake deposits in glacially blocked valleys tributary to the Spokane and Little Spokane valleys; may contain sand and ice-rafted boulders; merges with peat deposits near Newman Lake, Liberty Lake and Saltese flats. Recent and late Pleistocene.			
		Cm Cm/s	Colluvial silt Principally slopewash from aeolian and residual materials on mountain slopes; may contain colluvial sand and residual sand and gravel. Recent.	Poor, but variable Susceptible to erosion on slopes	Variable but generally adequate for light frame structures; heavier structures require special foundations Frost susceptible.	Usually stab... failures and ... subjected to...
SAND		As As/m	Alluvial sand Deposited along streams, principally along Latah Creek and Little Spokane River; locally grades into alluvial silts (Am) and gravel (Ag). Recent.	Generally poor due to high water table Good when above water table (As), but poor in silty areas (As/m)	Generally poor because of high water table and local interlayering with alluvial silts (Am)	Generally ... poor, due to...
		Ls Ls/g Ls/m	Lacustrine sand. Glacial outwash deposited in Pleistocene lakes, usually well sorted and stratified. May contain occasional silt or gravel.	Generally good, but affected by degree and type of stratification May be poor in near surface zones containing appreciable amounts of silt (Ls/m). Infiltration rates are generally high. Finer sands (Ls) subject to erosion on unprotected slopes.	Generally of medium density and suitable for most light structures. Loose zones may dictate special foundation treatment, particularly in dune sands(Ws). Limiting settlements usually govern foundation design. Frost susceptibility moderate to high, being most severe in areas containing appreciable silt.	Generally g... materials a... investigated... slopes exhib... should be ...
		Ws	Eolian sand. Dune deposits; wind reworked glacial outwash sand. Recent.	Generally good Subject to erosion on unprotected slopes		
		Gs Gs/g Gs/b Gs/m Gs/m/g Gs/g/m	Glacial outwash sand. Principally glacial fluvial deposits; includes some kame deposits and wind reworked surface dunes. Generally stratified and may contain occasional fine gravel or silt bedding. Pleistocene.	Generally good, but affected by degree and type of stratification Poor where appreciable silt is present (Gs/m, Gs/m/g). Finer sands (Gs) subject to erosion on slopes.		
		Rs/r Rs/r/r Rs/m/r Rs/g	Residual sand. Derived by weathering of metamorphic and granitic rocks; generally less than 3 ft thick, although may exceed 10 ft locally; contains gravel to boulder size residual rock fragments and may be mixed with glacial outwash or till, sand and gravel. Recent.	Generally poor due to high silt content (Rs/r/m, Rs/m/r) and proximity of parent rock. Good in silt-free areas (Rs/r, Rs/g).	Similar to above, although foundations will often penetrate through these soils and bear on underlying parent rock.	
		Cs/g Cs/g/m Cs/m Cs/m/r Cs/t	Colluvial sand-gravel. Principally slope wash from mountain slopes; includes residual material and is generally mixed with reworked loess. May be mixed locally with glacial outwash or till materials. Recent.	Highly variable, but generally poor due to silt content (Cs/g/m).	Similar to Ls, Ws and Gs series.	
GRAVEL		Ag/s/m Ag/s	Alluvial gravel. Deposited along portions of portions of Latah Creek and the Spokane River in bars and narrow terraces. Generally occurs with alluvial sands (As). Recent.	Permeability is very high, drainage poor due to high water within river and stream channels.	Suitable for most structures	Does not co... flattening.
		Gg/s b Gg/s Gg/m Gg/b Gg/s/m	Glacial flood and outwash gravel Principal deposit of the Spokane Valley. Mostly flood gravels deposited following breechings of ice dams in the Clark Fork and Coeur d'Alene Valleys. Upper 3 to 5 ft. is mixed with silt and sand; deposit is mostly coarse, poorly sorted gravel with some sand, cobbles and boulders. Pleistocene.	Good Permeability very high, drainage at surface low to moderate where mixed with silt (Gg/m, Gg/s/m).	Suitable for most struc' res	Natural slope... flattening... are unpredic...
ROCK AND SOIL MIXTURES		C(ta)b C(ta)s/m C(ta)s C(ta)m/s C(ta)m	Colluvial talus Gravity transported rock fragments from upslope rock outcrops; size ranges from gravel to "house" size blocks Large basalt blocks are locally called "haystacks". Talus is often mixed with silt and sand and locally overlaps outwash and till deposits. Recent	Generally poor due to high proportion of silt May be good at surface where silt is missing, and infiltrated water will flow through buried more pervious zones Runoff is high on slopes	Generally poor, but highly variable and individual sites must be investigated Generally found at the base of basalt cliffs in areas most difficult to investigate and develop.	Good to poor... will general... treatment. ... conditions.
		G(t)s G(t)s/b G(t)s/m	Glacial till. Sand to boulder size, unsorted morainal deposits; often mixed with silt and outwash material.	Highly variable depending on proportion of silt, sand and gravel. Generally moderate to good.	Generally good	Generally goo...
		C(ls)	Colluvial landslide deposits. Gravity transported local earth materials deposited under slide or flow conditions. Unsorted materials may range from clay to boulder sizes Recent.	Identified only at one remote location within ... area and sufficient data is not available to ... characteristics.		
FILL		Fs/g Fs/g/d Fr Fd	Manmade fills. Symbol shows predominant material where known. Sanitary landfills and mixed debris fills are designated Fd.	Because of the variable nature and generally ... development of areas underlain by manmade fill... by thorough investigation and study.		
ROCK		BA	Basalt rock Flows of dense, dark gray, jointed basalt of the Columbia River Group; essentially flat lying; may be tens of feet thick. Tertiary.	Fractured zones and flow contact zones in basalt may carry water Seepage often occurs along rock surfaces. Permeability varies from high to impervious according to the openness of fractured zones and the characteristics of the interbed or interformation contact.	Excellent. Heavily loaded areas on basalt should be explored to determine the presence of highly vesicular or fractured zones immediately below the footing	Steep slopes ... provided at ... with time, ... rock may ...
		ME	Metamorphic rock Primarily Belt series gneiss, schist and quartzite. The gneiss is typically banded and medium to coarse textured; the schist is typically contorted and fine to medium textured. Shallow to moderately deep alteration may occur locally. Pre-Cambrian.	Impervious where massive but may carry or store water in fractured zones, joints, or in weathered or altered zones Permeability is dependent upon degree of fracturing, openness of joints, and type and extent of alteration.	Generally excellent although highly weathered or altered sites may require special investigation	
		GR	Granitic rock. Medium to coarse grained; may be locally altered. Cretaceous.			
		ST	Siltstone (Latah Formation) Predominately consolidated lacustrine deposits but contains some alluvial silt and fine sand; tan, yellow or gray in color. Relatively soft where exposed. Underlies and is interbedded with the Columbia River basalt flows. Contains plant fossils. Tertiary.	Practically impervious Springs may flow along surface or through joints and fissures.	Hard, unweathered phases excellent Where exposed near surface and softened by weathering, foundation stability may be poor to good.	Generally goo... weathered ...

Notes: The general engineering evaluations listed above are based solely on judgment and knowledge of the generally defined soil and rock types. They are meant only for use in preliminary planning and development and are in no way intended to replace thorough site investigations.

Symbols For Material Origin

- A Alluvial
- C Colluvial
- F Fill (man-made)
- G Glacial
- L Lacustrine
- R Residual
- W Eolian

Special Qualifying Symbols

- (t) Glacial till
- (ta) Talus
- (ls) Landslide

Symbols For Material Classification

- b Boulders
- c Clay
- d Debris
- g Gravel
- m Silt
- r Rock rubble
- s Sand
- BA Basalt bedrock
- ME Metamorphic bedrock
- GR Granite bedrock
- ST Siltstone (Latah Fm)

[DR]AINAGE	FOUNDATION STABILITY	SLOPE STABILITY	EXCAVATION
. Permeability usually high in [...]ally if peat is consolidated	Not suitable for building foundations. Embankment fill loads may settle several inches and settlements will continue over several years	Does not occur on natural slopes; steep slopes relatively stable when dry, but unstable when wet.	Usually requires dredging or dragline operation
[...]ate in zones with a high [...]ighly susceptible to erosion on	Generally adequate for light frame structures; heavy structures usually require special foundations; semi-stable particle structure may cause large settlements upon saturation. Frost susceptible.	Usually stable when dry Wet condition may produce shallow failures and mud flows on natural slopes, particularly when subjected to freeze-thaw cycles Shallow (10 ft.) excavation slopes will usually remain stable at steep angles unless unfavorable groundwater conditions are present; high slopes should be cut back or shored.	Can generally be excavated with hand or power equipment, but mobility of equipment is poor under wet conditions
[...]ly impervious Generally occurs [...]low.	Not regarded as a suitable foundation soil Settlements may be excessive and irregular. Frost susceptible.	Generally does not occur on slopes Excavation stability poor in wet areas. May stand on steep slopes temporarily in dry areas.	Generally easy to excavate with hand or power equipment, but mobility of equipment is poor under wet conditions
[...]to erosion on slopes	Variable but generally adequate for light frame structures; heavier structures require special foundations Frost susceptible.	Usually stable when dry Wet condition may produce shallow failures and mud flows on natural slopes, particularly when subjected to freeze-thaw.	Can generally be excavated with hand or power [eq]uipment, but mobility of equipment is poor under wet conditions
[...]table Good when above water [...]es (As/m).	Generally poor because of high water table and local interlayering with alluvial silts (Am).	Generally does not occur on slopes Excavation stability poor, due to high water Slopes must be flattened or shored.	Can generally be excavated with hand or power equipment above water table. Dredging, dragline, etc required below water unless site is dewatered. Presence of silts (As/m) will reduce equipment mobility.
[...]egree and type of stratification. [...] containing appreciable amounts [...]es are generally high. Finer [...] unprotected slopes.	Generally of medium density and suitable for most light structures. Loose zones may dictate special foundation treatment, particularly in dune sands(Ws). Limiting settlements usually govern foundation design. Frost susceptibility moderate to high, being most severe in areas containing appreciable silt.	Generally good, but may be marginal where underlying impervious materials and springs are present. Hillside sites should be investigated. Excavation slopes must be flattened. Steep slopes exhibit temporary stability, but are unpredictable and should be shored.	Can generally be excavated with hand or power equipment.
[...] on unprotected slopes.			
[...]egree and type of stratification. [...]esent (Gs/m, Gs/m/g). Finer [...] slopes.			Can generally be excavated with hand or power equipment. Boulders (Gs/b) may require special handling.
[...]ontent (Rs/r/m, Rs/m/r) and [...] silt-free areas (Rs/r,Rs/g).	Similar to above, although foundations will often penetrate through these soils and bear on underlying parent rock.		
[...] due to silt content (Cs/g/m).	Similar to Ls, Ws and Gs series.		
[...] poor due to high water within	Suitable for most structures.	Does not occur on natural slopes Excavation slopes require flattening.	Can generally be excavated with power equipment. Dredging required below water. High permeability and proximity to rivers and stream often make dewatering impracticable without special treatment.
[...]ainage at surface low to moderate [...]/m).	Suitable for most struc[tu]res	Natural slopes are generally stable Excavation slopes require flattening. Steep slopes exhibit temporary stability, but are unpredictable and should be shored.	Can generally be excavated with power equipment Large boulders (Gg/b, Gg/s/b) may require special handling.
[...]tion of silt May be good at [...] infiltrated water will flow [...]. Runoff is high on slopes.	Generally poor, but highly variable and individual sites must be investigated. Generally found at the base of basalt cliffs in areas most difficult to investigate and develop.	Good to poor; individual sites must be investigated Excavations will generally encounter local seepage that may require special treatment. Steep slopes may remain stable depending upon local conditions.	Excavation difficult because of presence of large boulders and haystacks which usually must be broken up by blasting Heavy power equipment generally required.
[...]ortion of silt, sand and gravel.	Generally good.	Generally good.	Can generally be excavated with power equipment. Large boulders may require special handling
	Identified only at one remote location within the urbanizing area and sufficient data is not available to evaluate engineering characteristics.		
	Because of the variable nature and generally uncontrolled placement, development of areas underlain by manmade fills must be preceded by thorough investigation and study.		
[...] zones in basalt may carry water. [...]urfaces. Permeability varies [...] to the openness of fractured [...] the interbed or interformation	Excellent. Heavily loaded areas on basalt should be explored to determine the presence of highly vesicular or fractured zones immediately below the footing.	Steep slopes will generally remain stable. Safety area should be provided at the toe to catch spalls and blocks that may loosen with time, particularly in basalt. Highly fractured and weathered rock may require slope flattening.	Generally requires blasting Heavy power equipment and rippers sometimes have success removing highly fractured basalt, but this condition cannot always be determined beforehand
[...] carry or store water in [...]athered or altered zones. [...]egree of fracturing, openness [...] alteration.	Generally excellent although highly weathered or altered sites may require special investigation.		
[...] may flow along surface or	Hard, unweathered phases excellent Where exposed near surface and softened by weathering, foundation stability may be poor to good.	Generally good in deep unweathered phases Poor in softer weathered zones if spring water is present.	Unweathered Latah requires power equipment; softer phases can be excavated by machine or by hand with picks.

[...] Origin

Symbols For Material Classification

	b	Boulders
	c	Clay
[...]de)	d	Debris
	g	Gravel
	m	Silt
	r	Rock rubble
	s	Sand
	BA	Basalt bedrock
[...] Symbols	VZ	Metamorphic bedrock
	GR	Granite bedrock
[...]ill	ST	Siltstone (Latah Fm.)

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

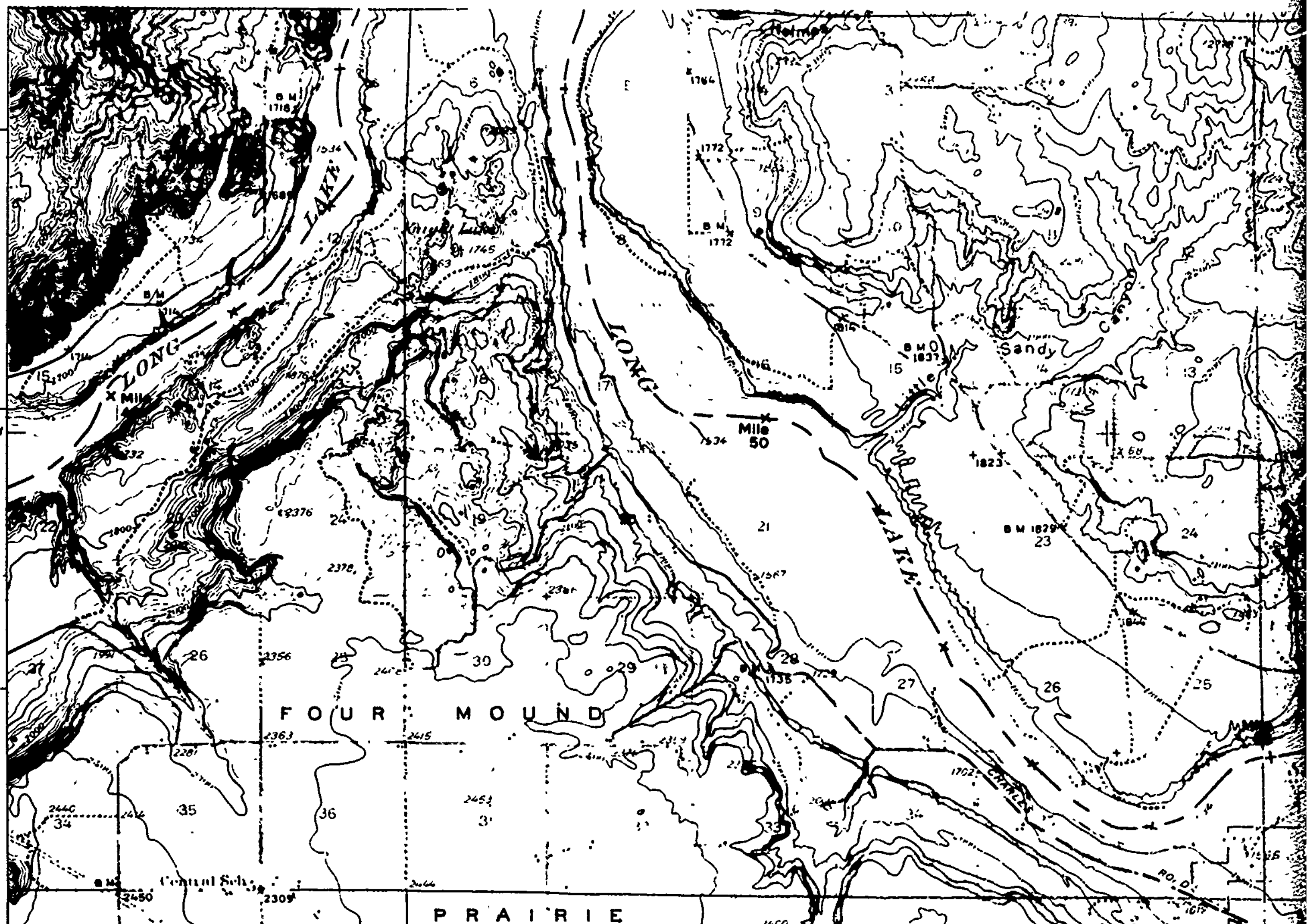
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY LEGEND

DACW67-73-C-0096

PLATE 303-3



1/2 0 1 MILE

GRAPHIC SCALES

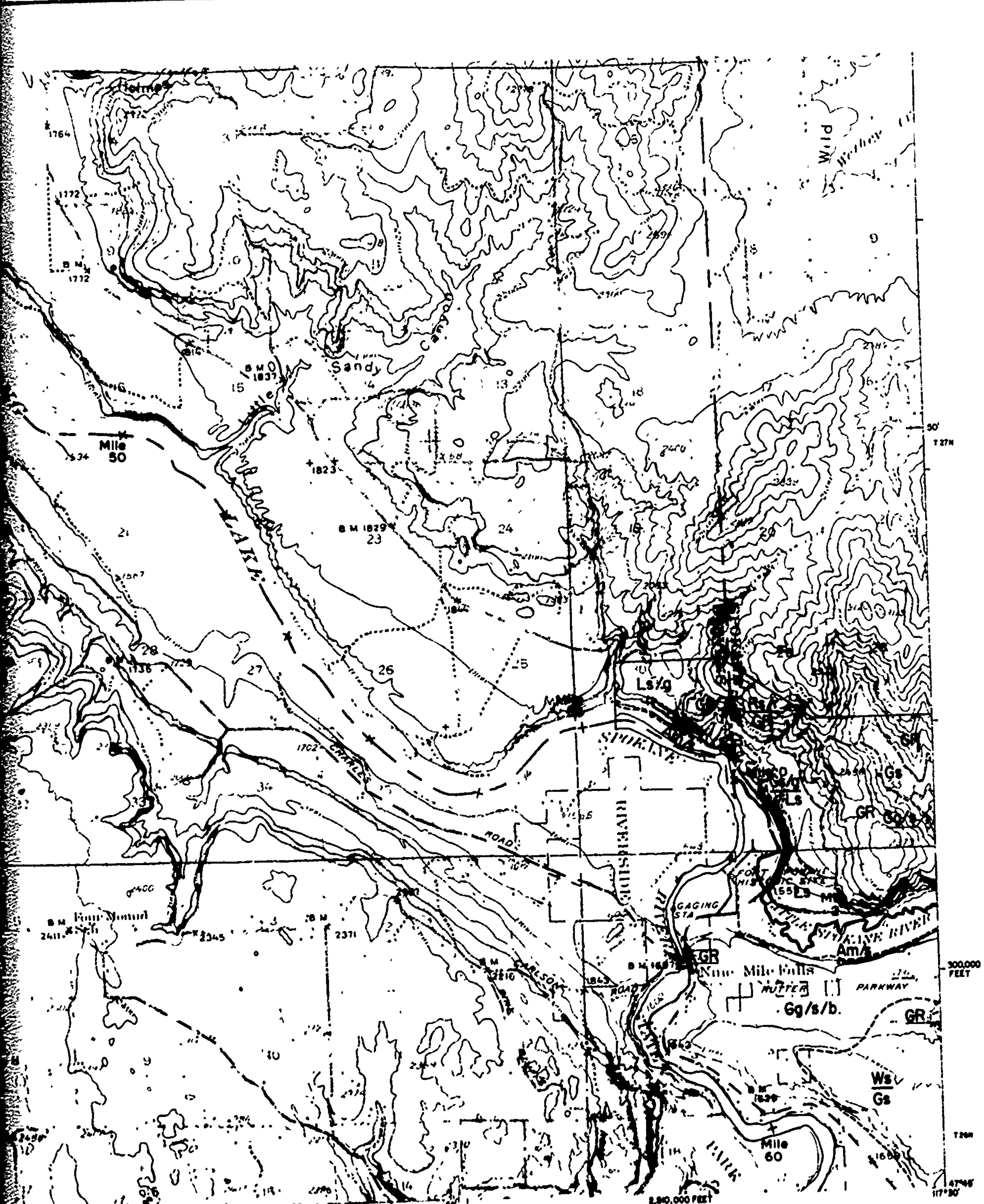
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SOURCE: USGS CLAYTON, WASH. QUADRANGLE, 15 MINUTE SERIES, 1950

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide

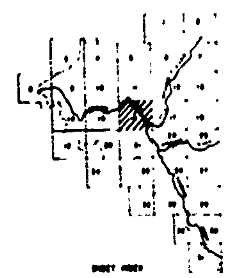


MAP SOURCE: USGS CLAYTON, WASH. QUADRANGLE, 15 MINUTE SERIES, 1950

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

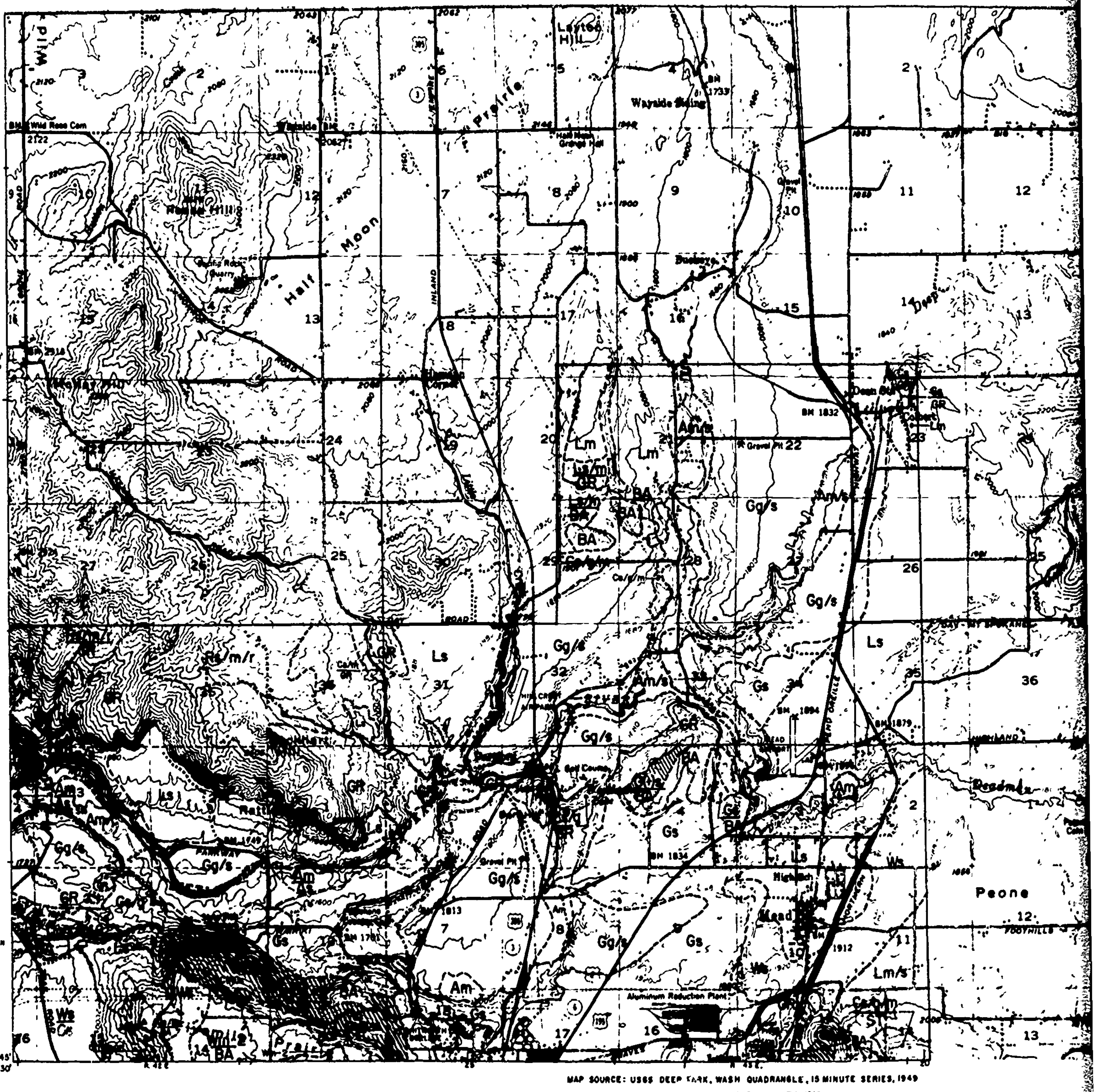
WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY
AREA 16

DACW67-73-C-0090

PLATE 303-4

2



MAP SOURCE: USGS DEEP PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

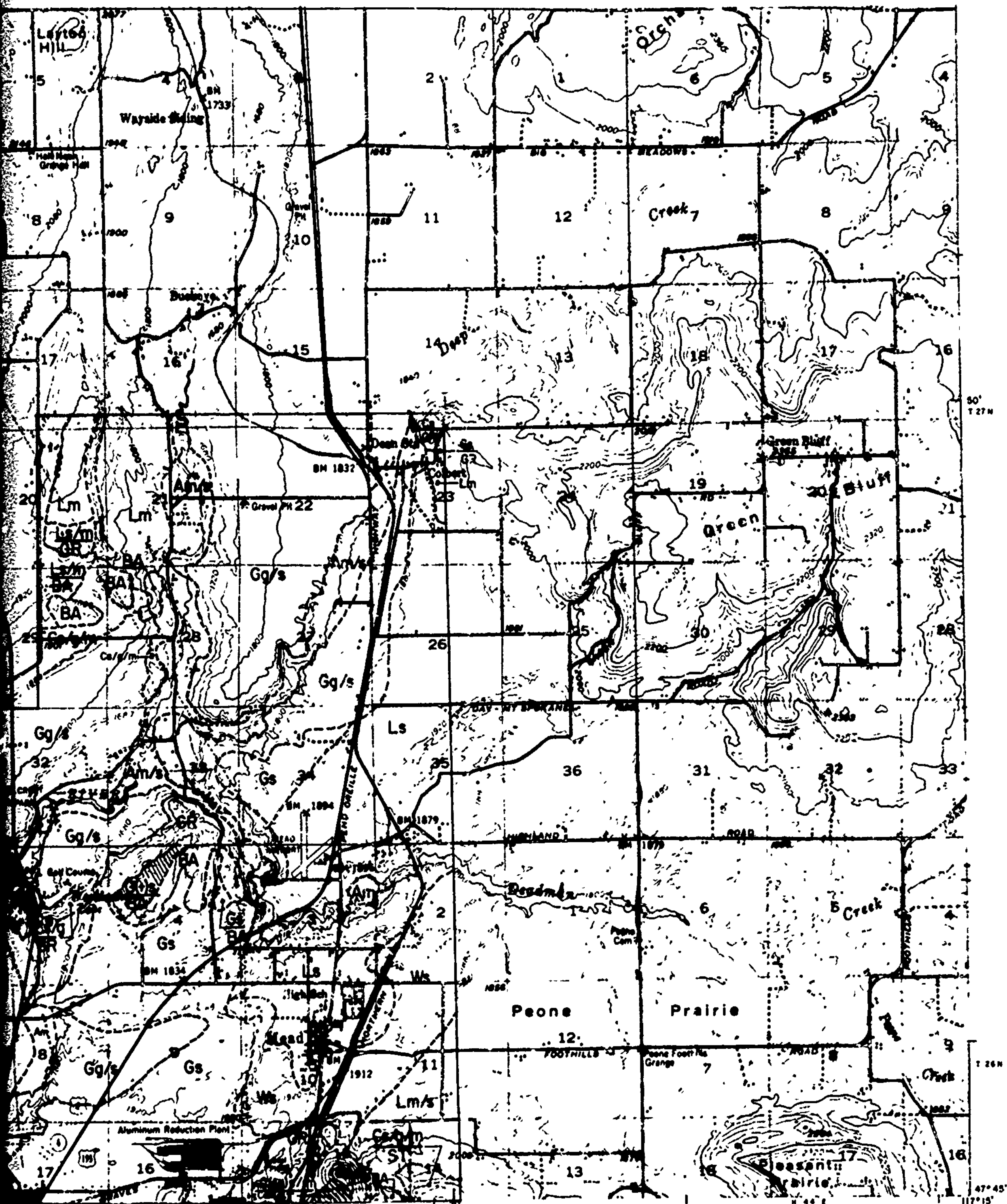
GRAPHIC SCALES

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

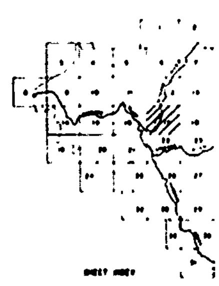


MAP SOURCE: USGS DEER PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

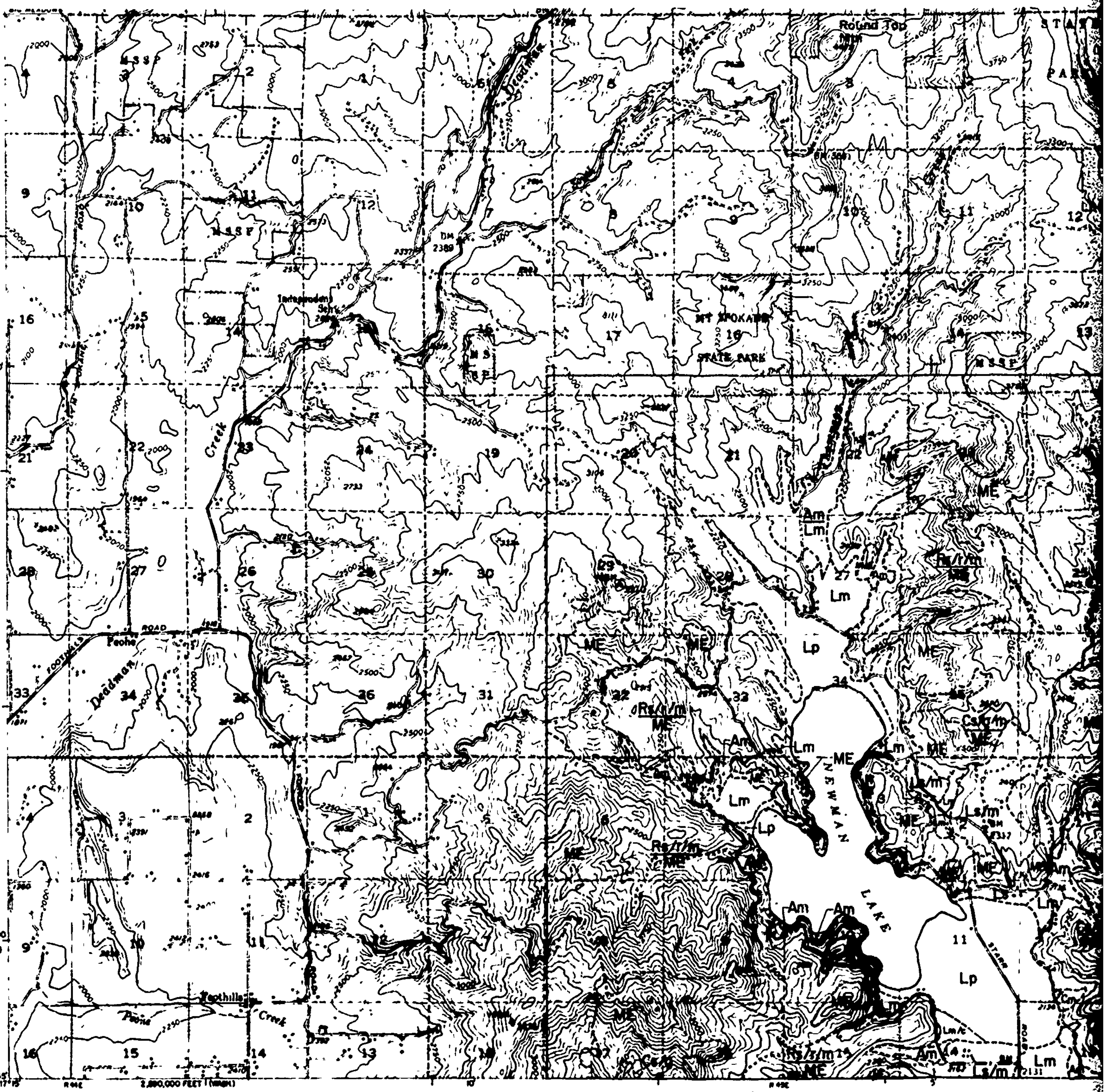
WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY
AREA 17

DACW67-73-C-0096

"PLATE 303-5"

2



MAP SOURCE: USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1980

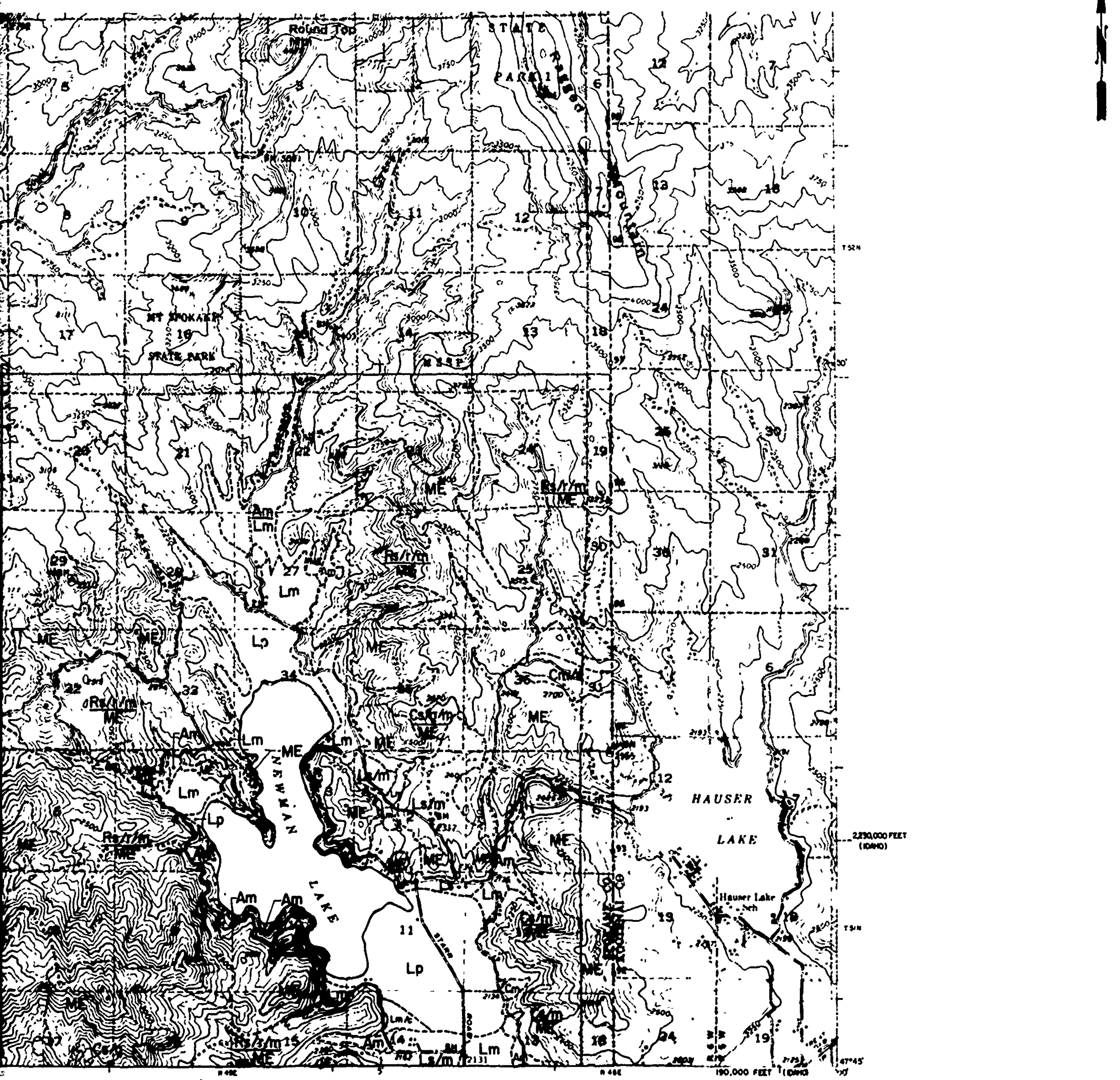
GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta)-talus
(f)-fill
(ls)-landslide

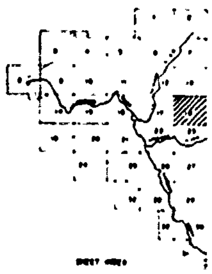


MAP SOURCE: USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1950

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta)-talus
(f)-fill
(ls)-landslide



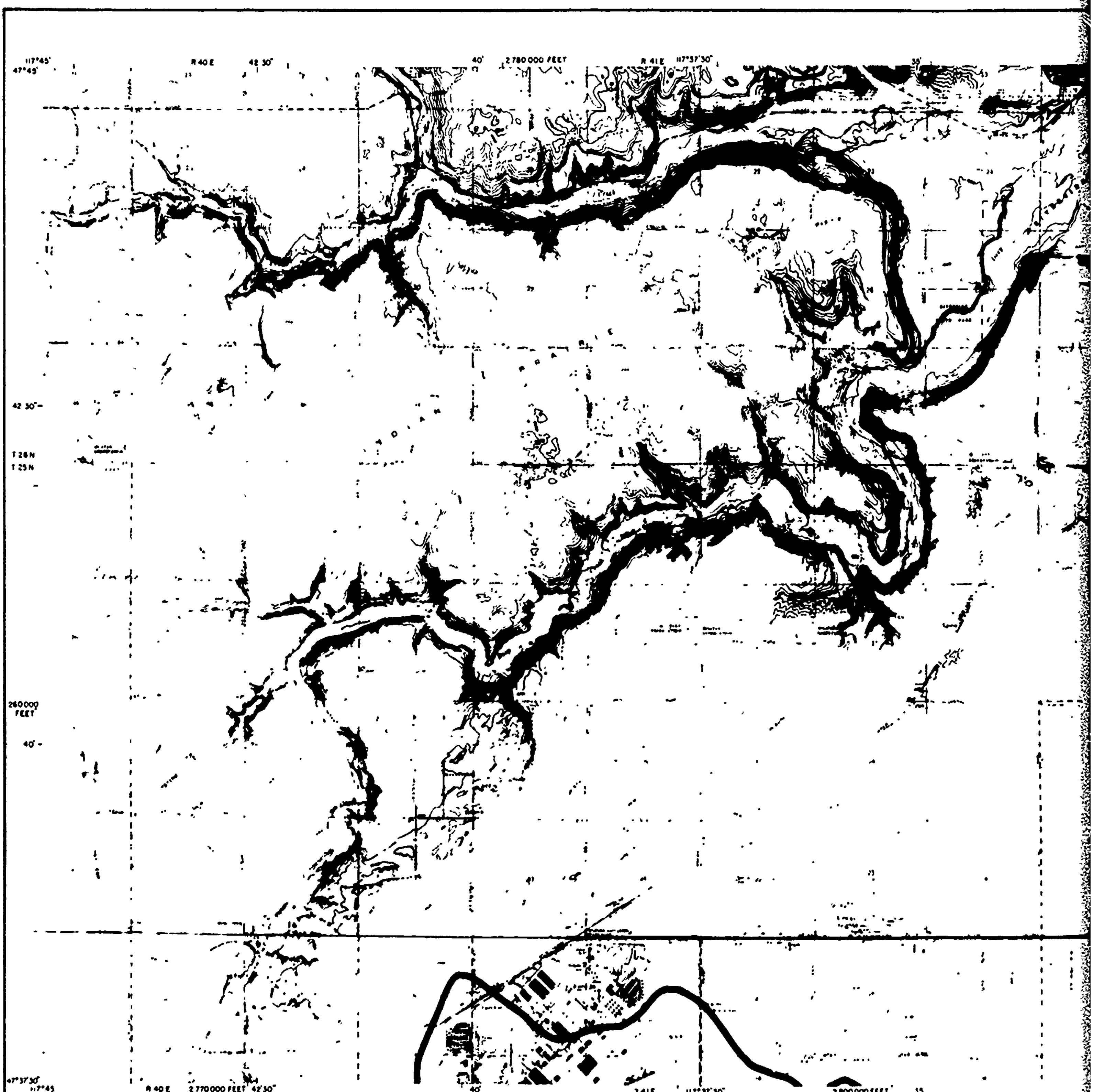
TUDOR CONSULTING ENGINEERS SEATTLE, WASHINGTON	U S ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY
AREA 18

DACW67-73-C-0090

PLATE 303-6



MAP SOURCE: USGS DEEP CREEK, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE: USGS AIRWAY HEIGHTS WASH

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

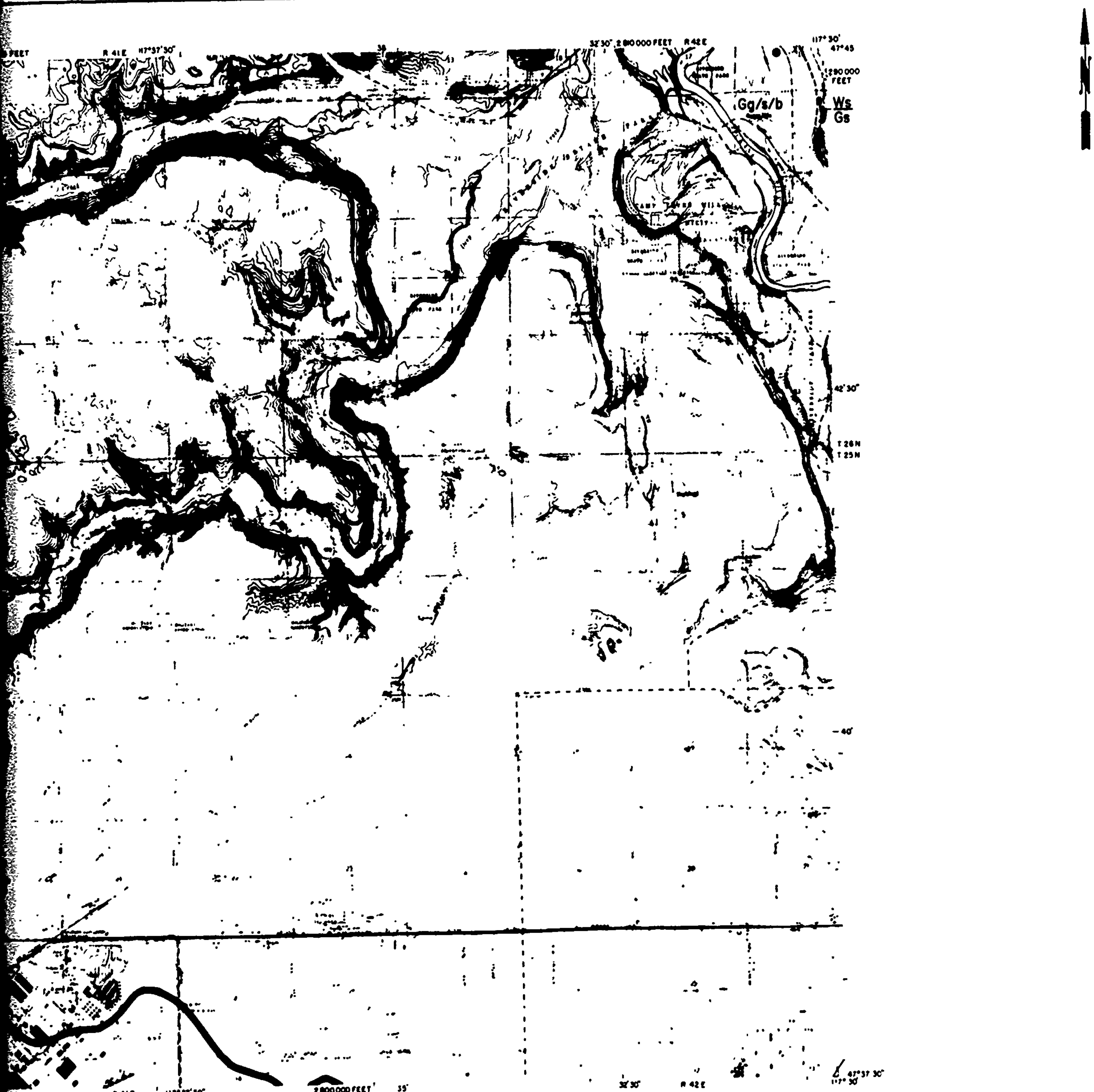
GRAPHIC SCALES

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) Talus
(t) Till
(ls) Landslide

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



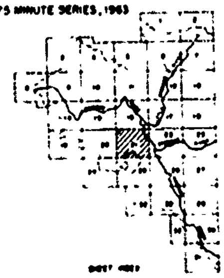
MAP SOURCE USGS AIRWAY HEIGHTS WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

SERIES, 1963

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) Talus
(t) Till
(ls) Landslide



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

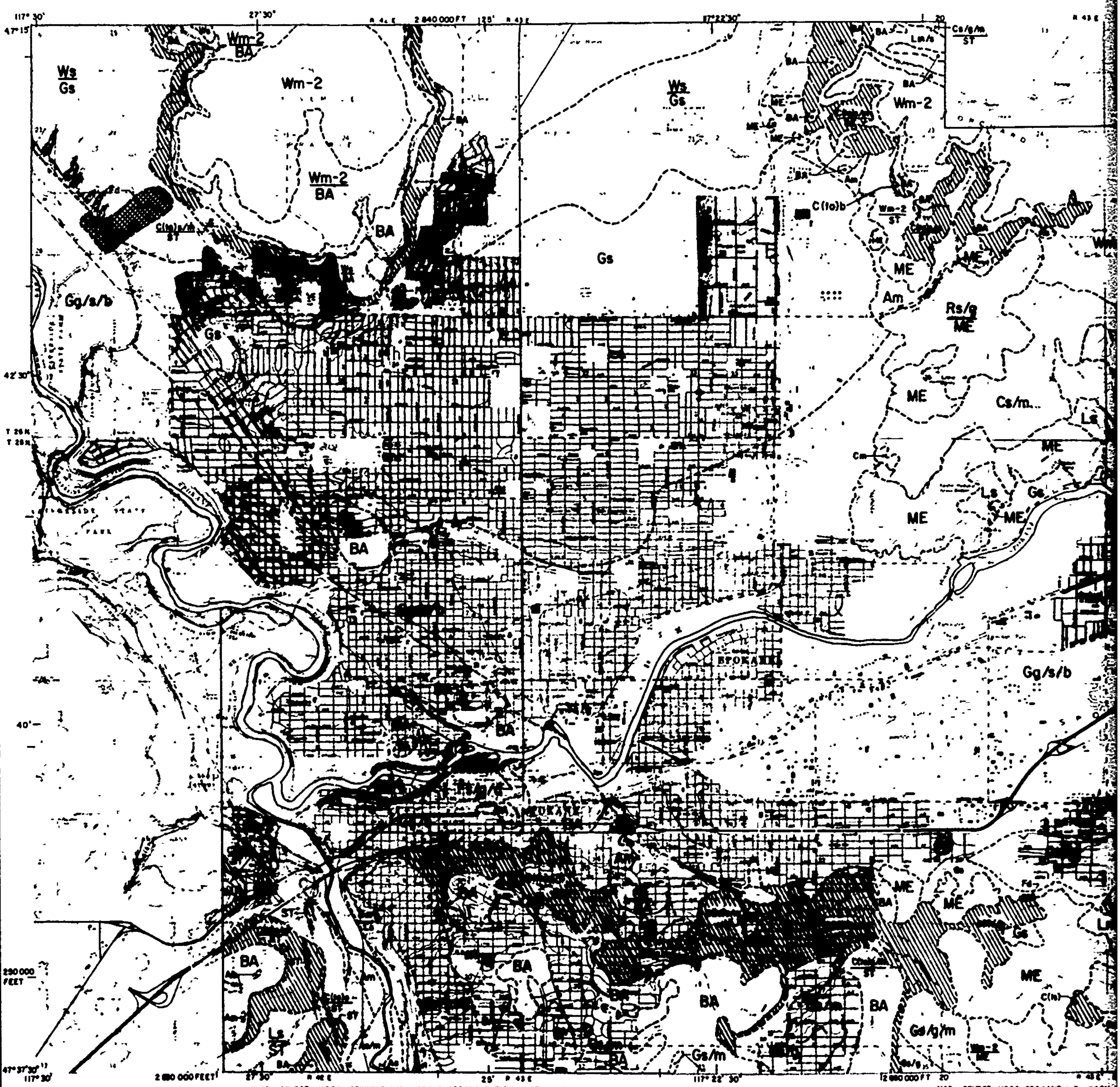
WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY
AREA 21

DACW67-73-C-0096

"PLATE 303-7"

2



MAP SOURCE: USGS SPOKANE N.W., WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE N.E., WASH.

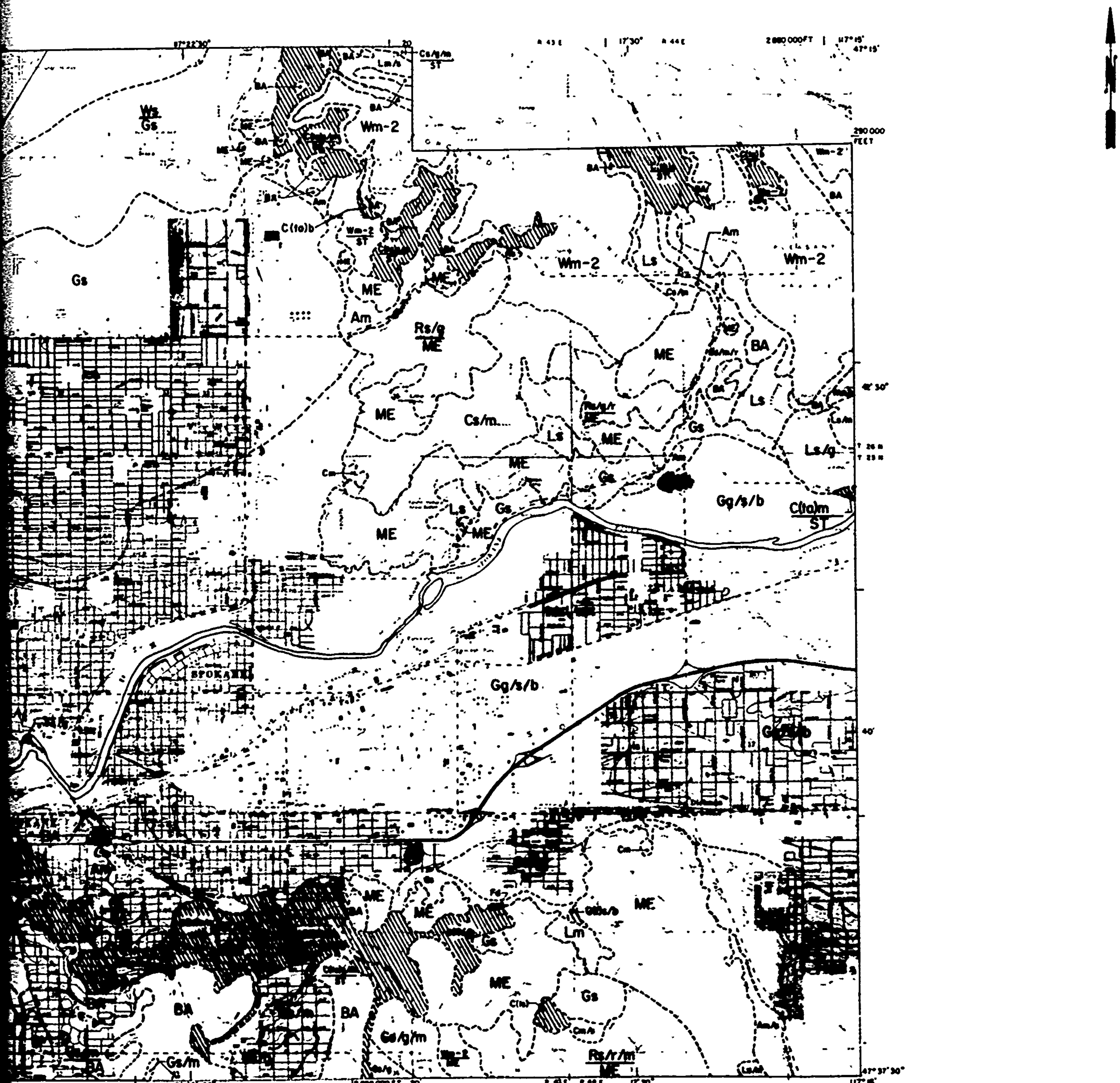
GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide



MAP SOURCE USGS SPOKANE N.E., WASH. QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta)-Talus
(t)-Till
(ls)-Landslide

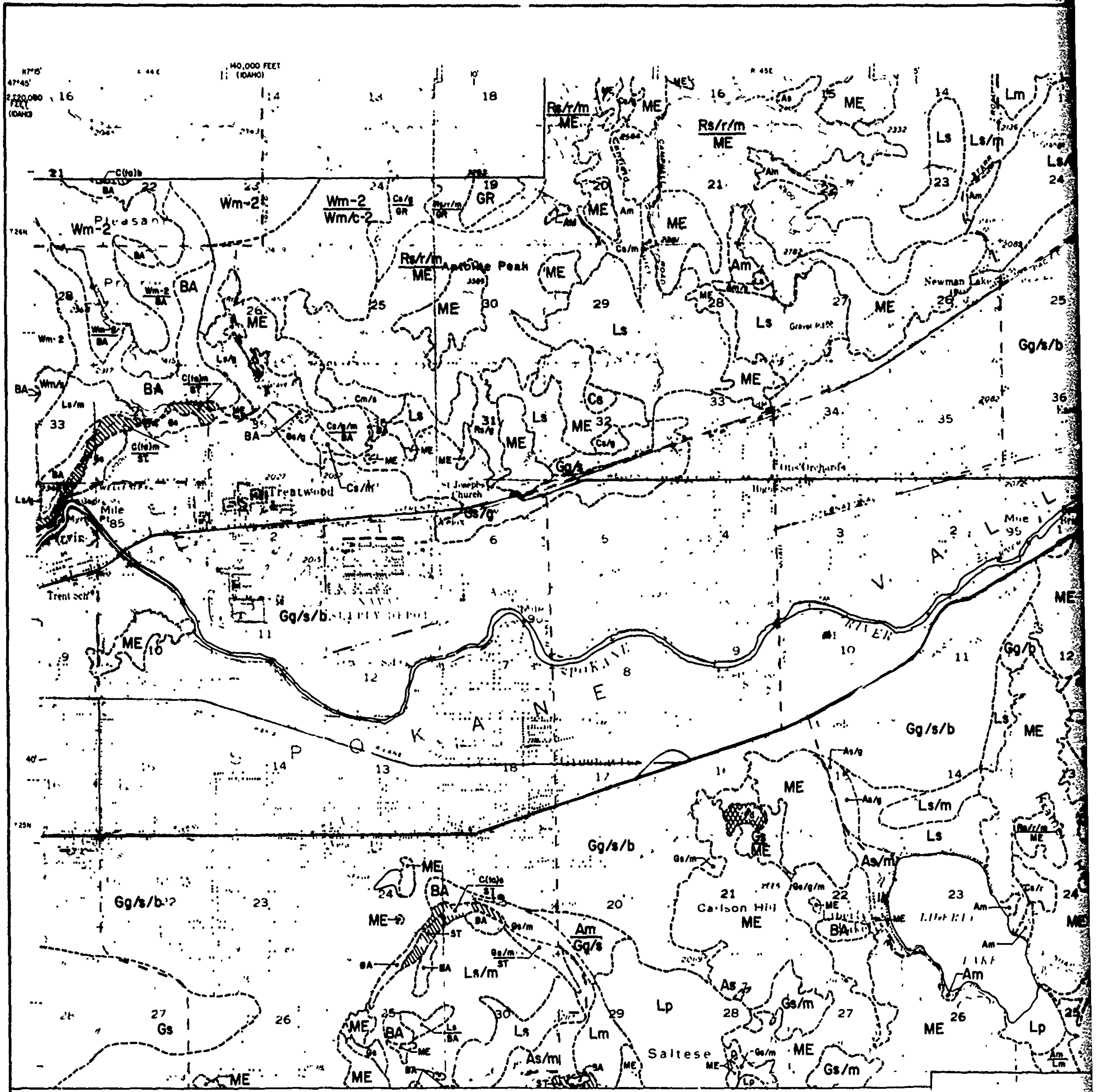
KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

U.S. ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY
AREA 22

PLATE 303-8



GRAPHIC SCALES

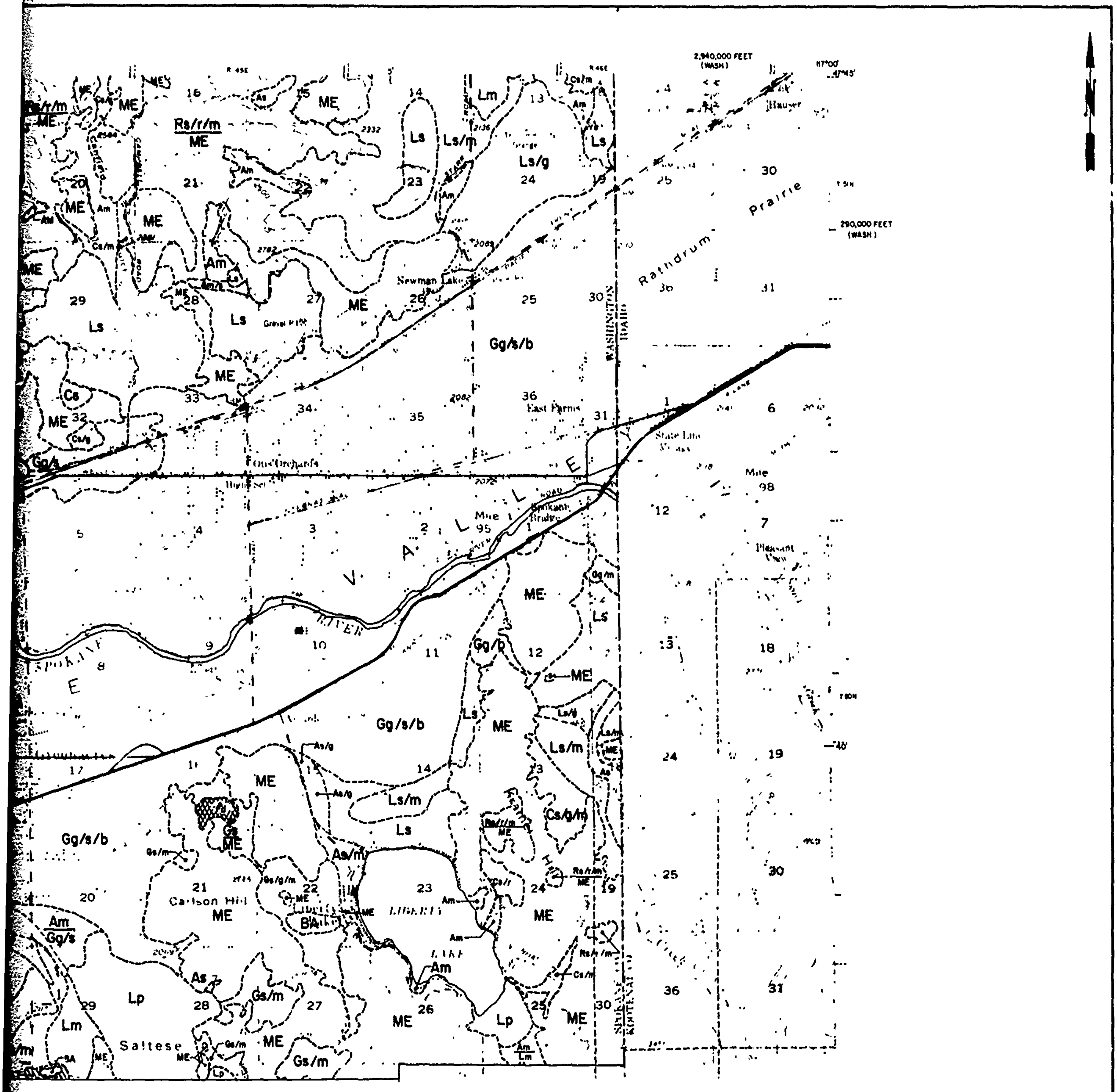
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide



MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) – Talus
(t) – Till
(ls) – Landslide

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

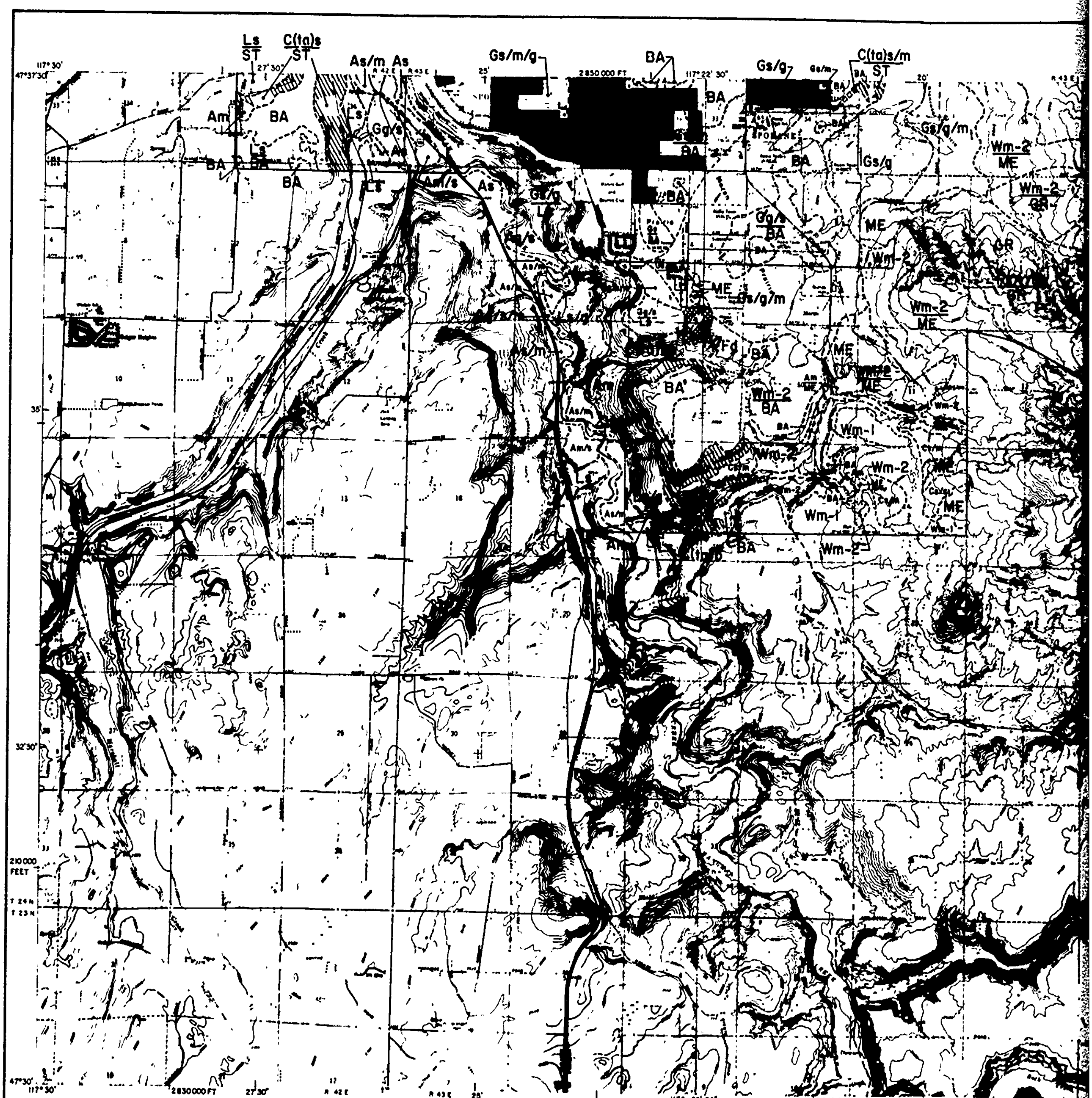
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

ENGINEERING GEOLOGY
AREA 23

DACW67-73-C-0096

PLATE 303-9



MAP SOURCE USGS SPOKANE S.W., WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE S.W., WASH QUADRANGLE, 7.5

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

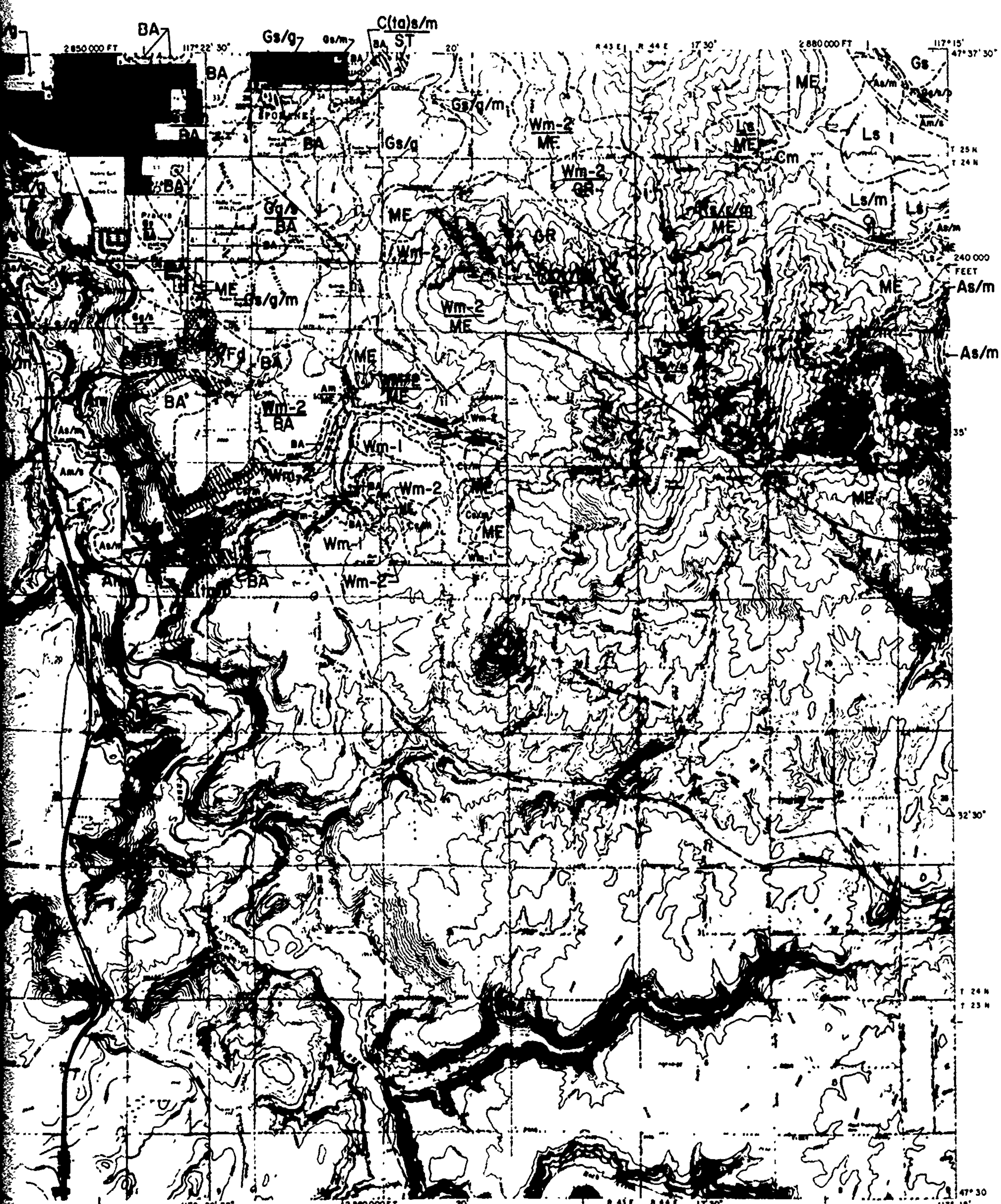
GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
f	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide



MAP SOURCE USGS SPOKANE S ‾, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) - Till
(ls) - Landslide

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

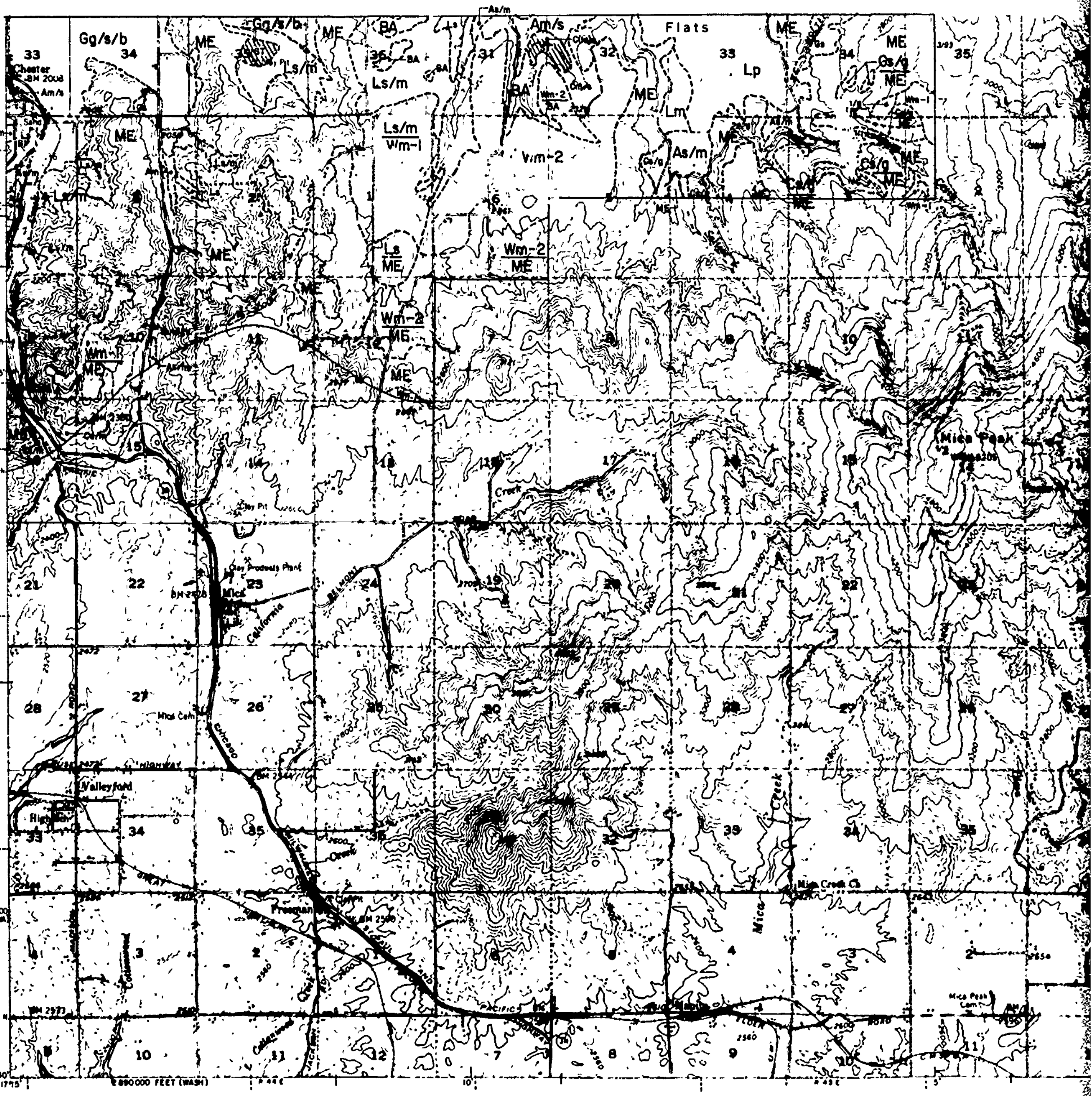
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

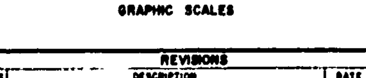
ENGINEERING GEOLOGY
AREA 26

DACW67-73-C-0096

PLATE
303-10



MAP SOURCE. USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949



GRAPHIC SCALES

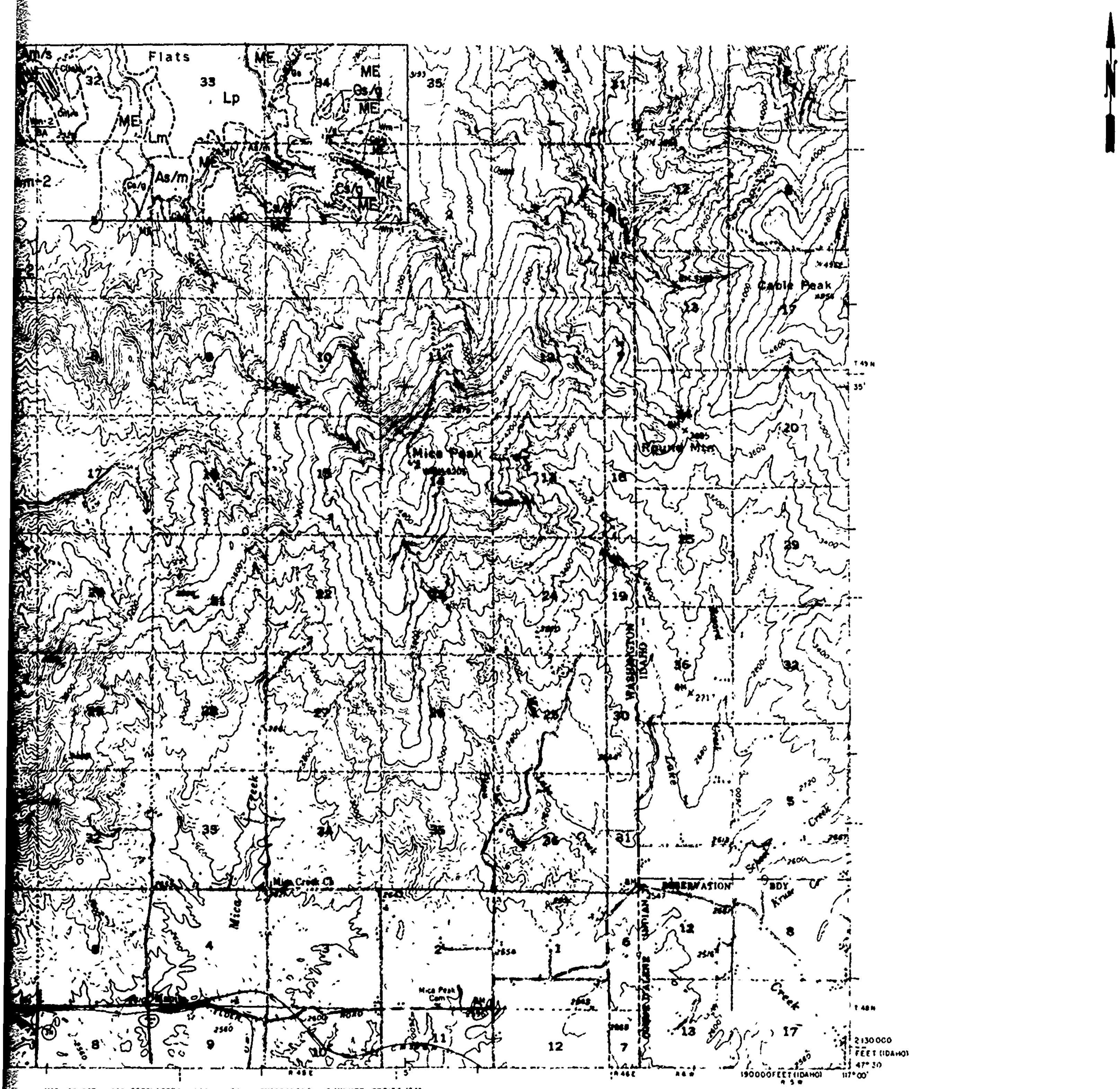
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
f	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS

(ta)- Talus
(t) Till
(ls) Landslide

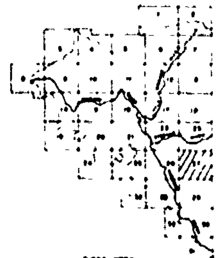


MAP SOURCE USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

MAP SYMBOL LEGEND

MATERIAL ORIGIN		SOIL		ROCK	
A	Alluvial	c	Clay	BA	Basalt
C	Colluvial	m	Silt	ME	Metamorphic
F	Fill (manmade)	s	Sand	GR	Granite
G	Glacial	g	Gravel	ST	Siltstone (Latah Formation)
L	Lacustrine	b	Boulders		
R	Residual	r	Rock rubble		
W	Eolian	d	Debris		
		p	Peat		

SPECIAL SYMBOLS
(ta) - Talus
(t) Till
(ls) Landslide



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

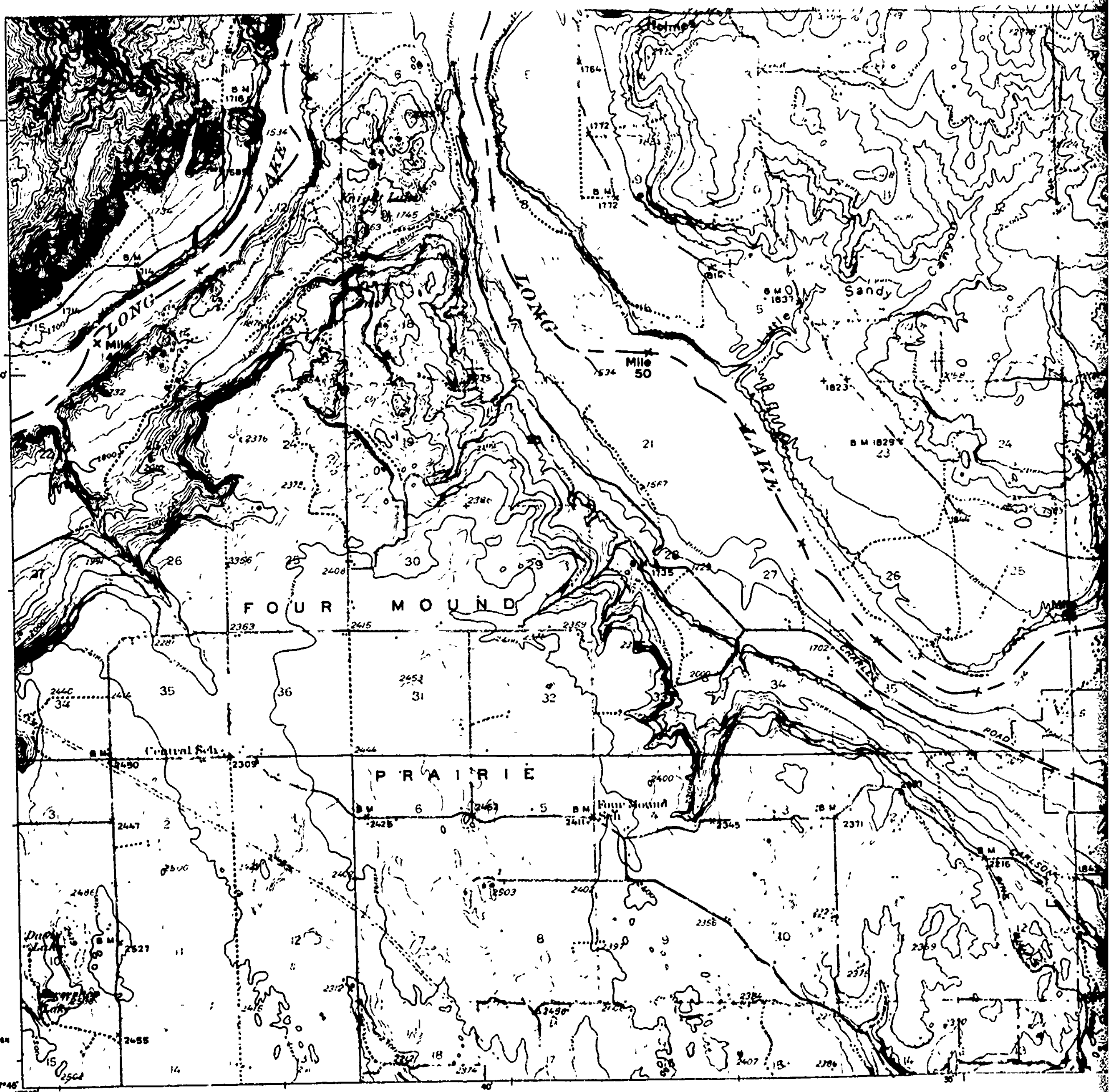
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

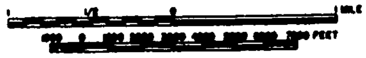
ENGINEERING GEOLOGY
AREA 27

DACW67-73-C-0096

PLATE 303-11



MAP SOURCE: USGS CLAYTON, WASH. QUADRANGLE, 15 MINUTE SERIES, 1950



GRAPHIC SCALES

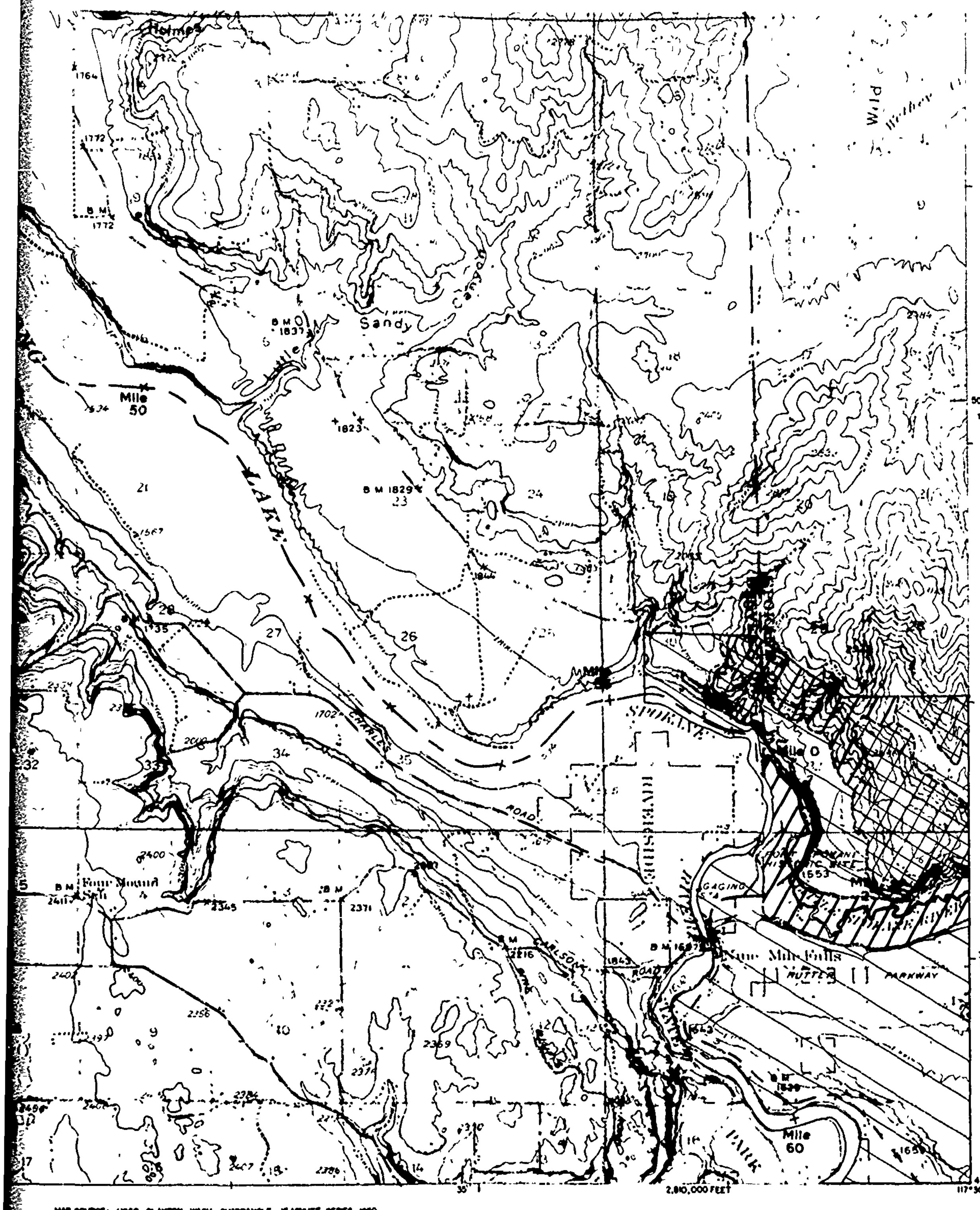
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wn, Am, Lm Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface



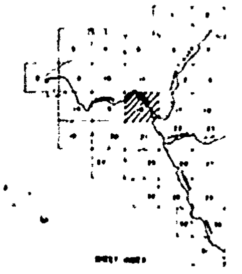
MAP SOURCE: USGS CLAYTON, WASH QUADRANGLE, 15 MINUTE SERIES, 1950

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands silty sands and gravels, silts	Wn, Am, Lm Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface



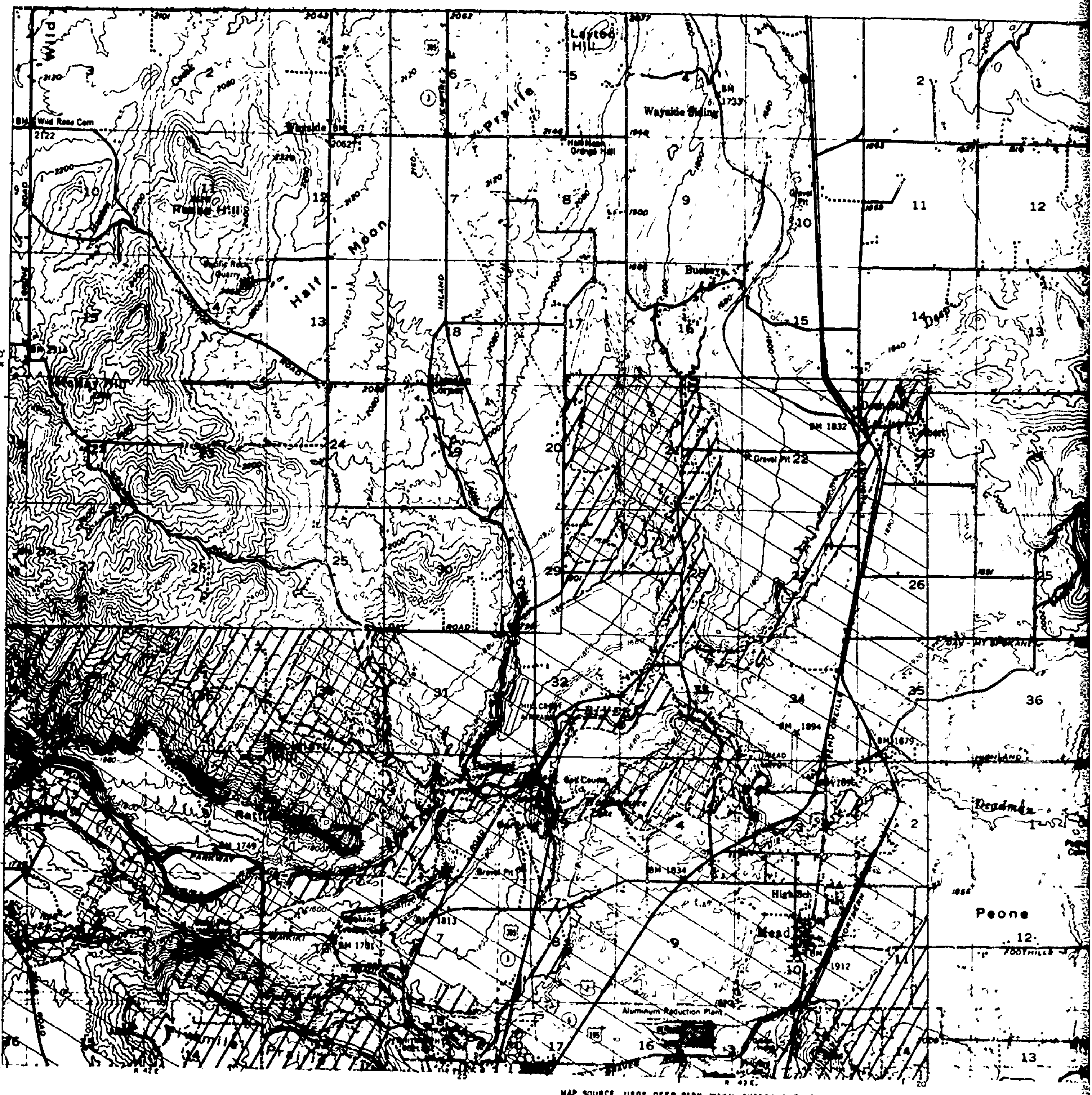
KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION
SURFACE PERMEABILITY
AREA 16

DACW67-73-C-0006

"PLATE 303-12"



GRAPHIC SCALES

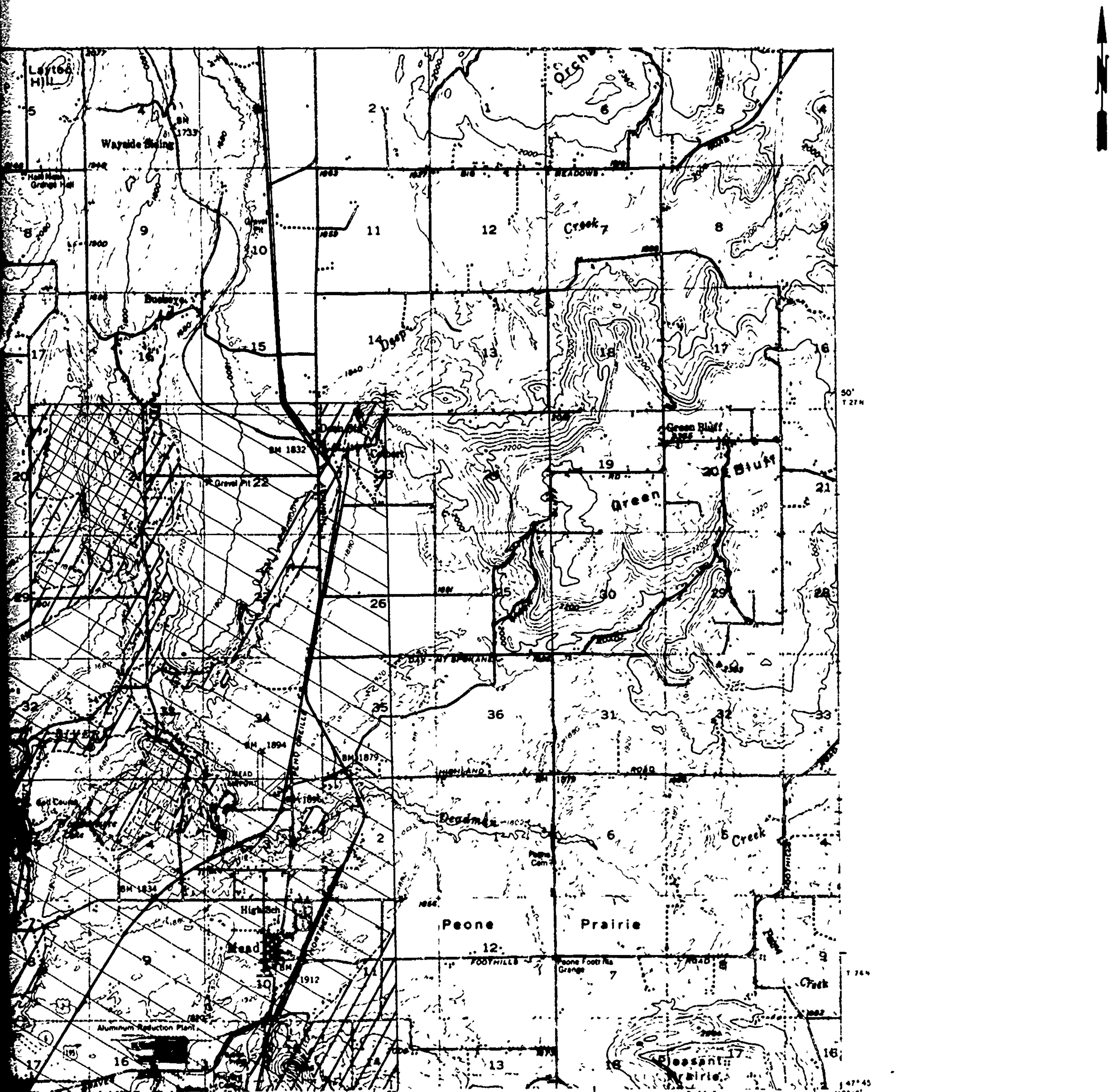
REVISIONS			
	DESCRIPTION	DATE	BY

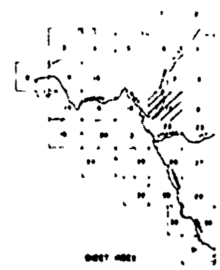
LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability repre[...] relative permeability of the [...] soils within about 3 feet of [...] ground surface





MAP SOURCE. USGS DEER PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface.

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

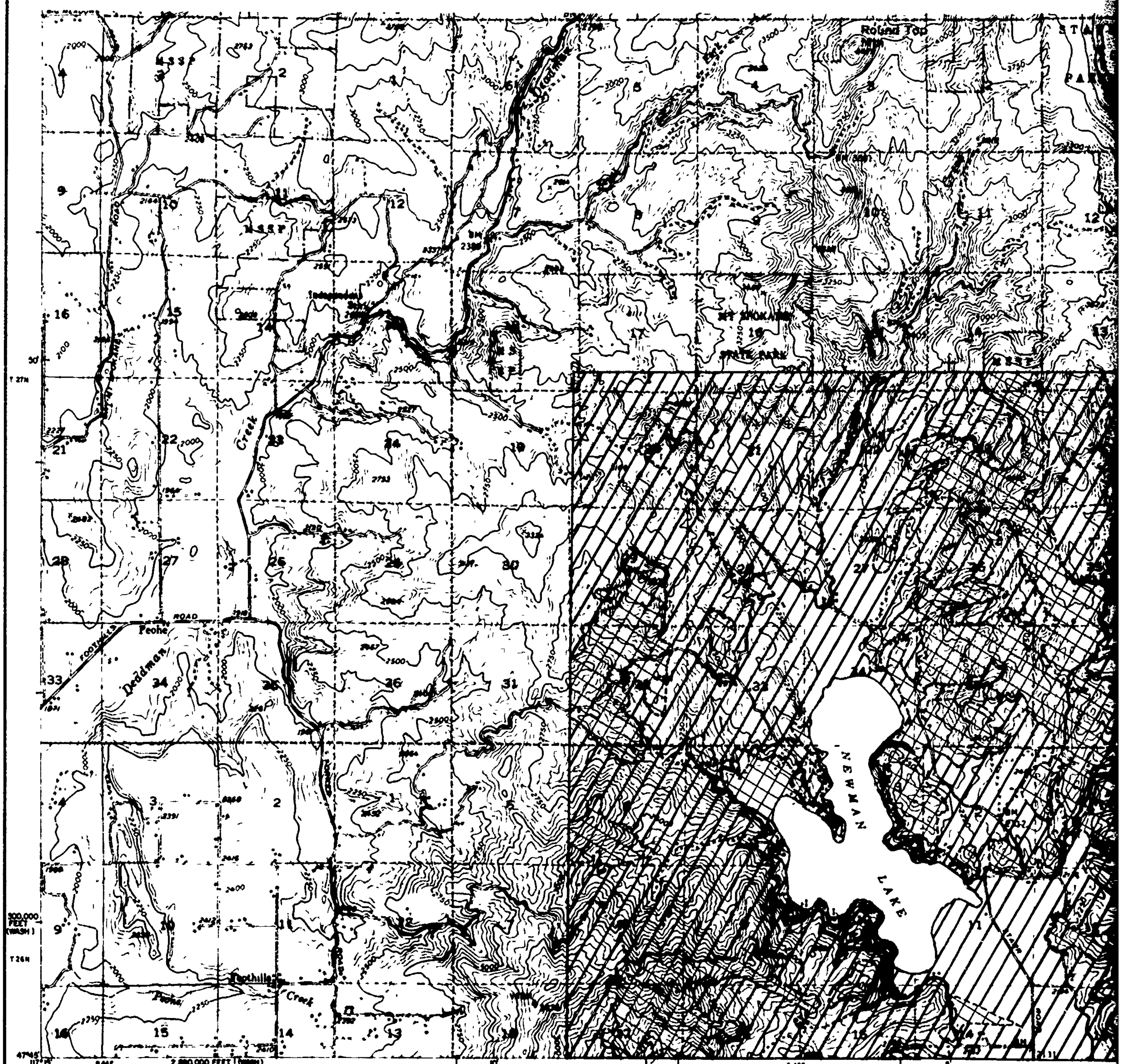
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

SURFACE PERMEABILITY
AREA 17

DACW67-73-C-0096

PLATE 303-13



GRAPHIC SCALES

MAP SOURCE: USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1900

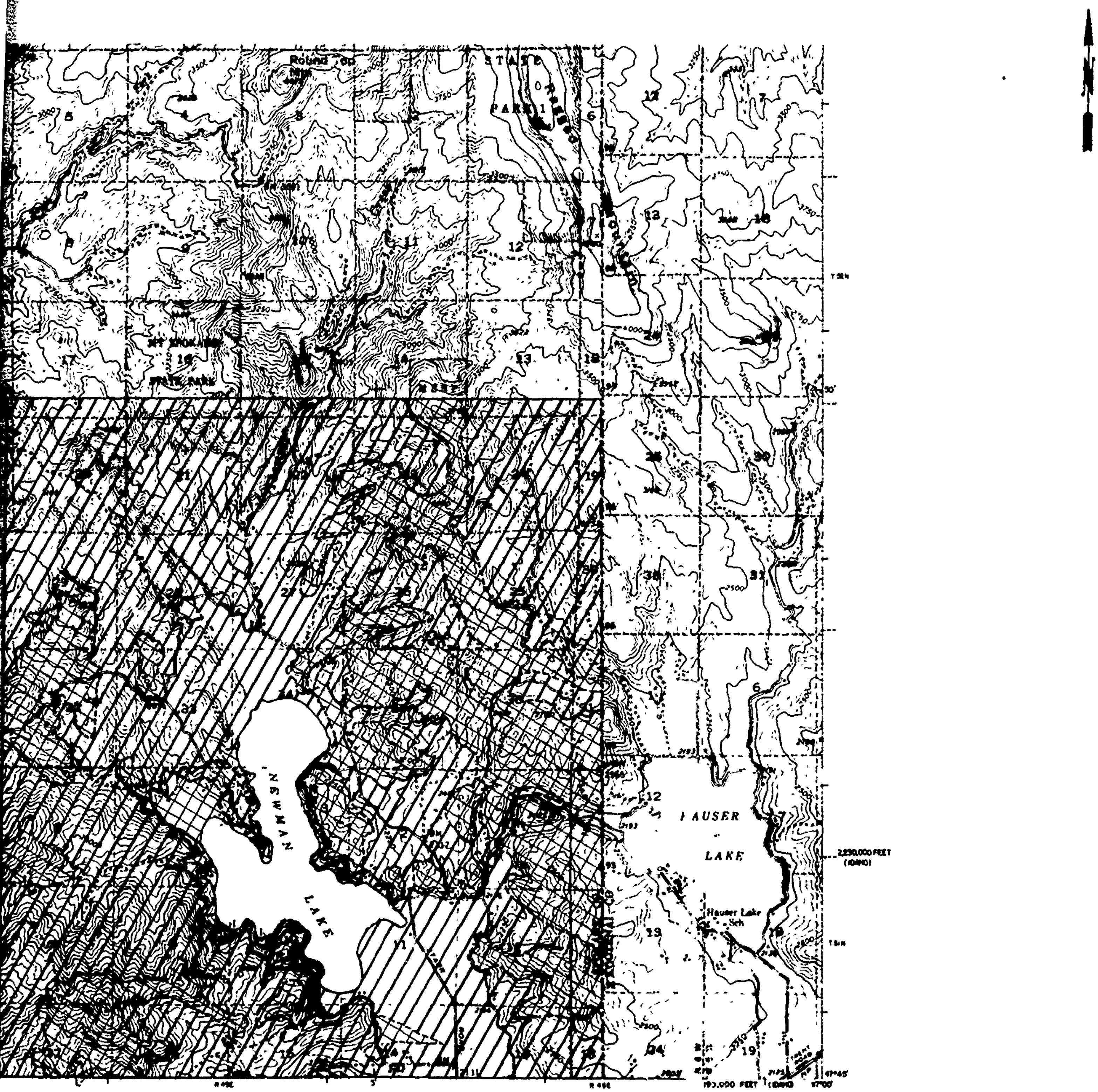
LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability repre[sents] relative permeability of the soils within about 3 feet of ground surface.

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



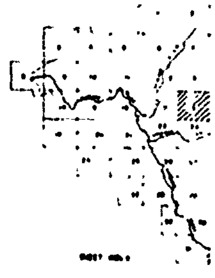
MAP SOURCE: USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1950

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface.



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

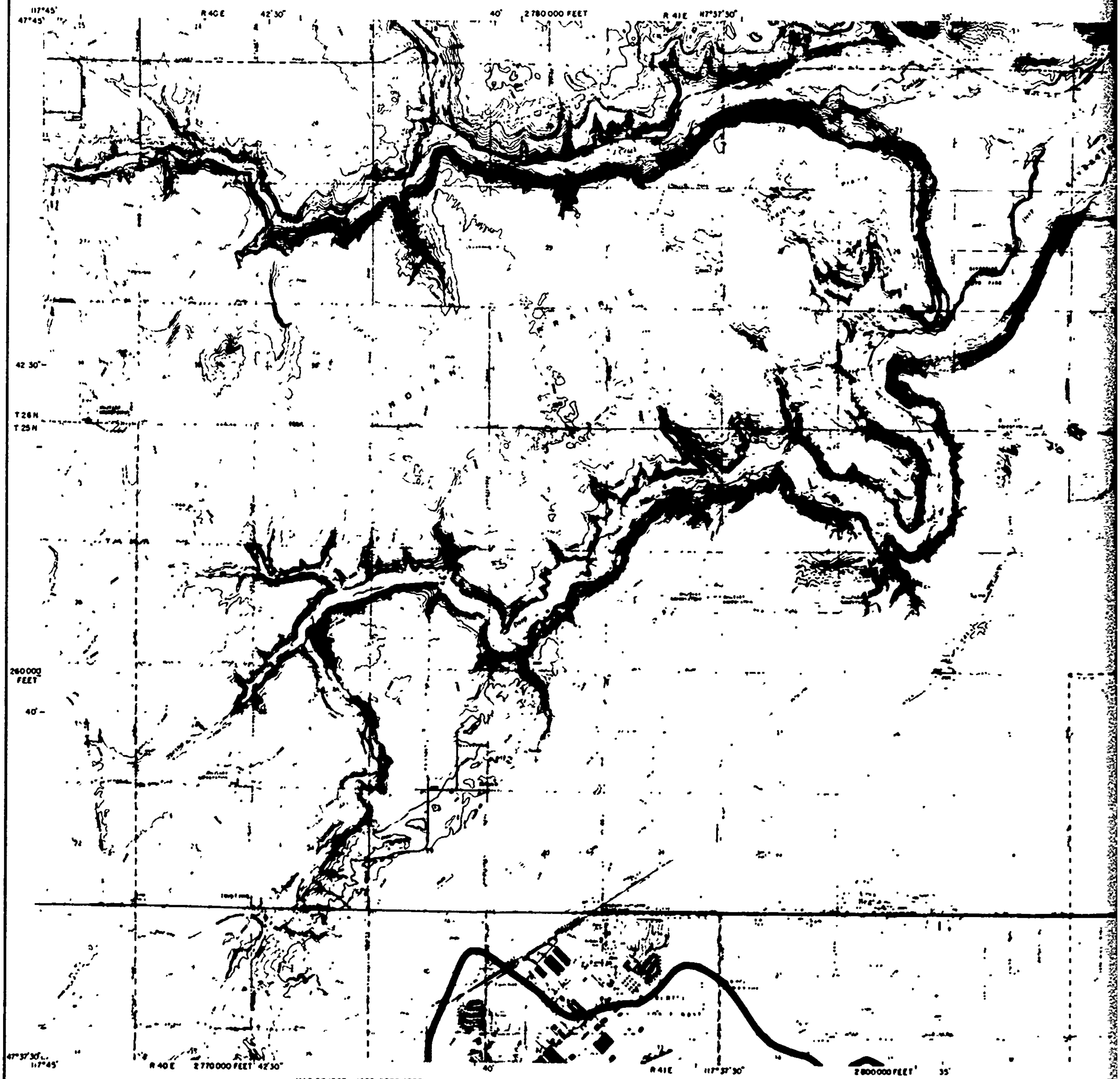
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

SURFACE PERMEABILTY
AREA 18

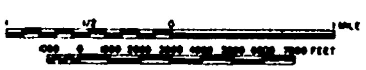
DACW67-73-C-0090

PLATE 303-14



MAP SOURCE: USGS DEEP CREEK, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS AIRWAY HEIGHTS WASH



GRAPHIC SCALES

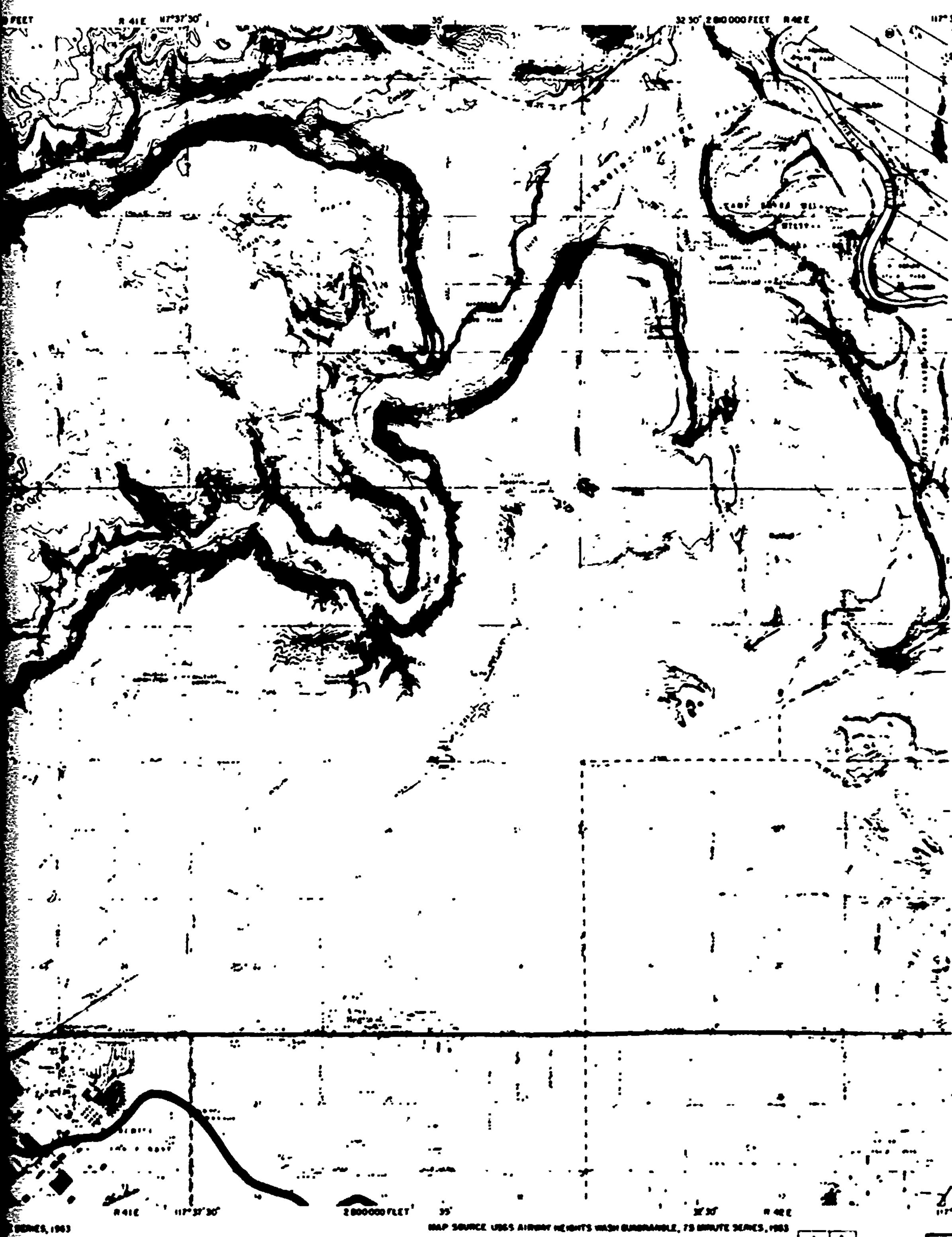
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability
relative permeability of
soils within about 3 feet
ground surface.



MAP SOURCE USGS AIRWAY HEIGHTS WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
	High	$>10^{4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

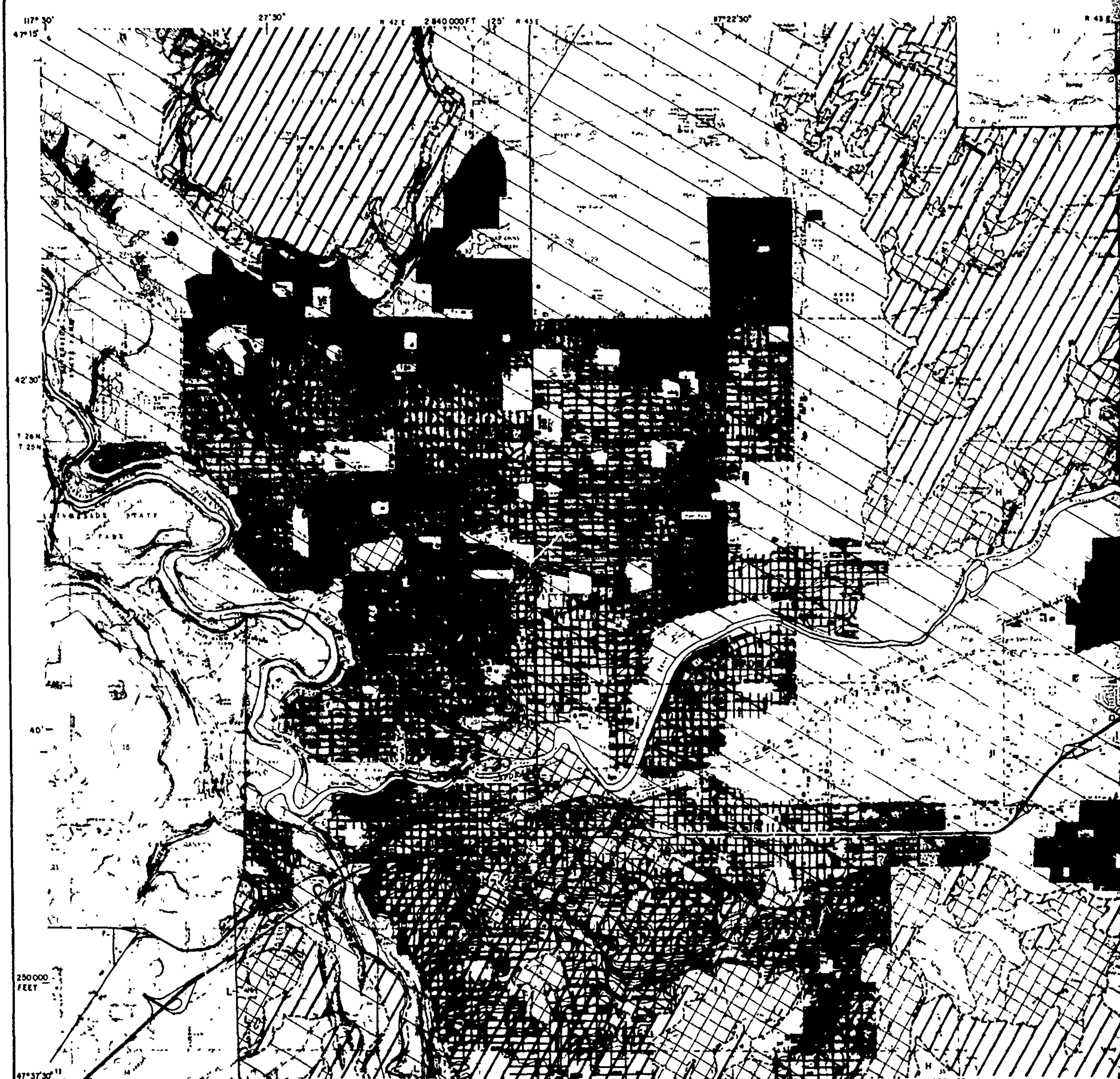
NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface.

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

SURFACE PERMEABILITY
AREA 21

PLATE 303-15



MAP SOURCE USGS SPOKANE NW, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE N E, WASH.

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

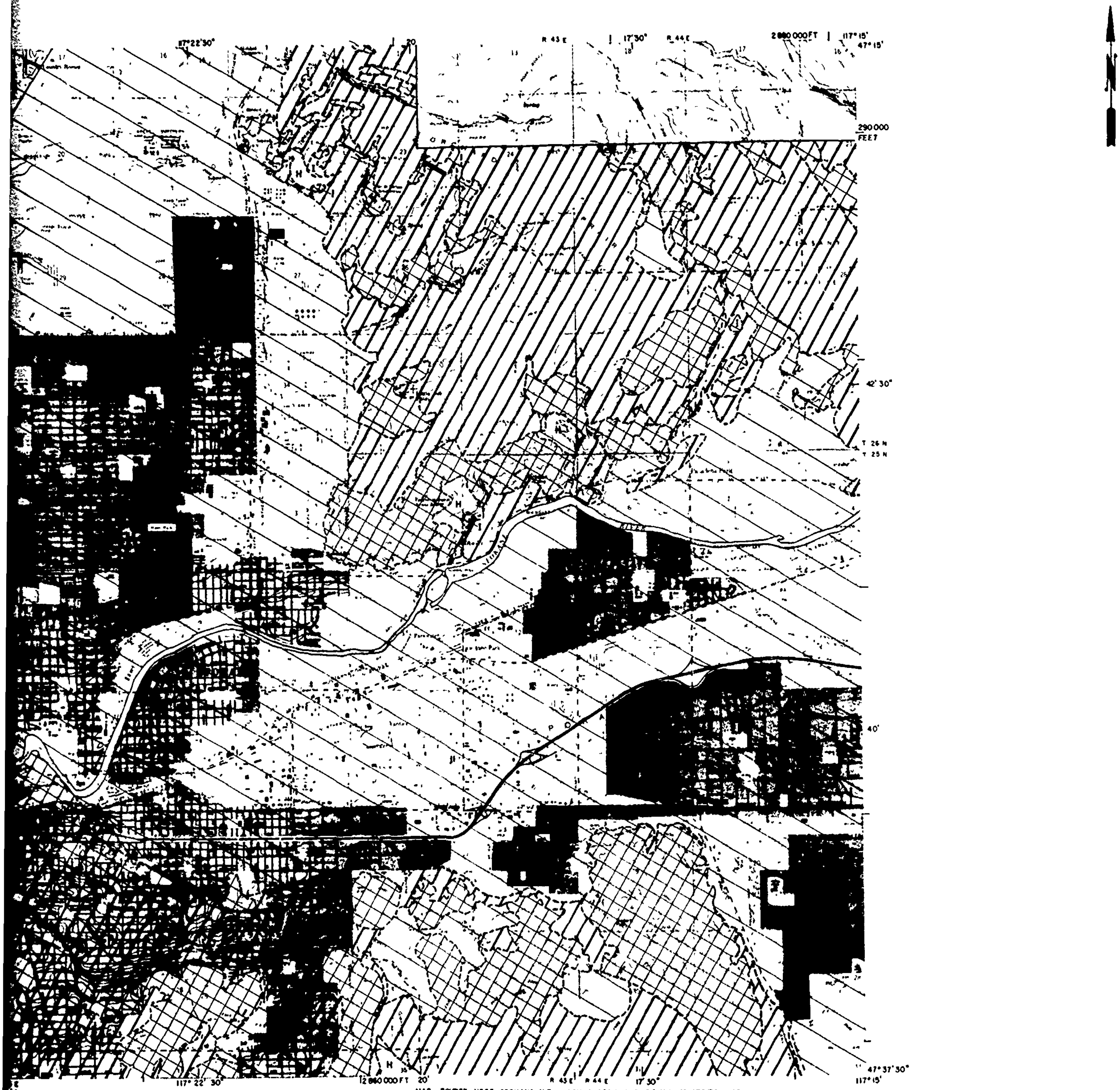
LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{4}-10^{6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



...TE SERIES, 1963

MAP SOURCE USGS SPOKANE N.E., WASH. QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface.

KENNEDY TUDOR
CONSULTING ENGINEERS
SEATTLE WASHINGTON

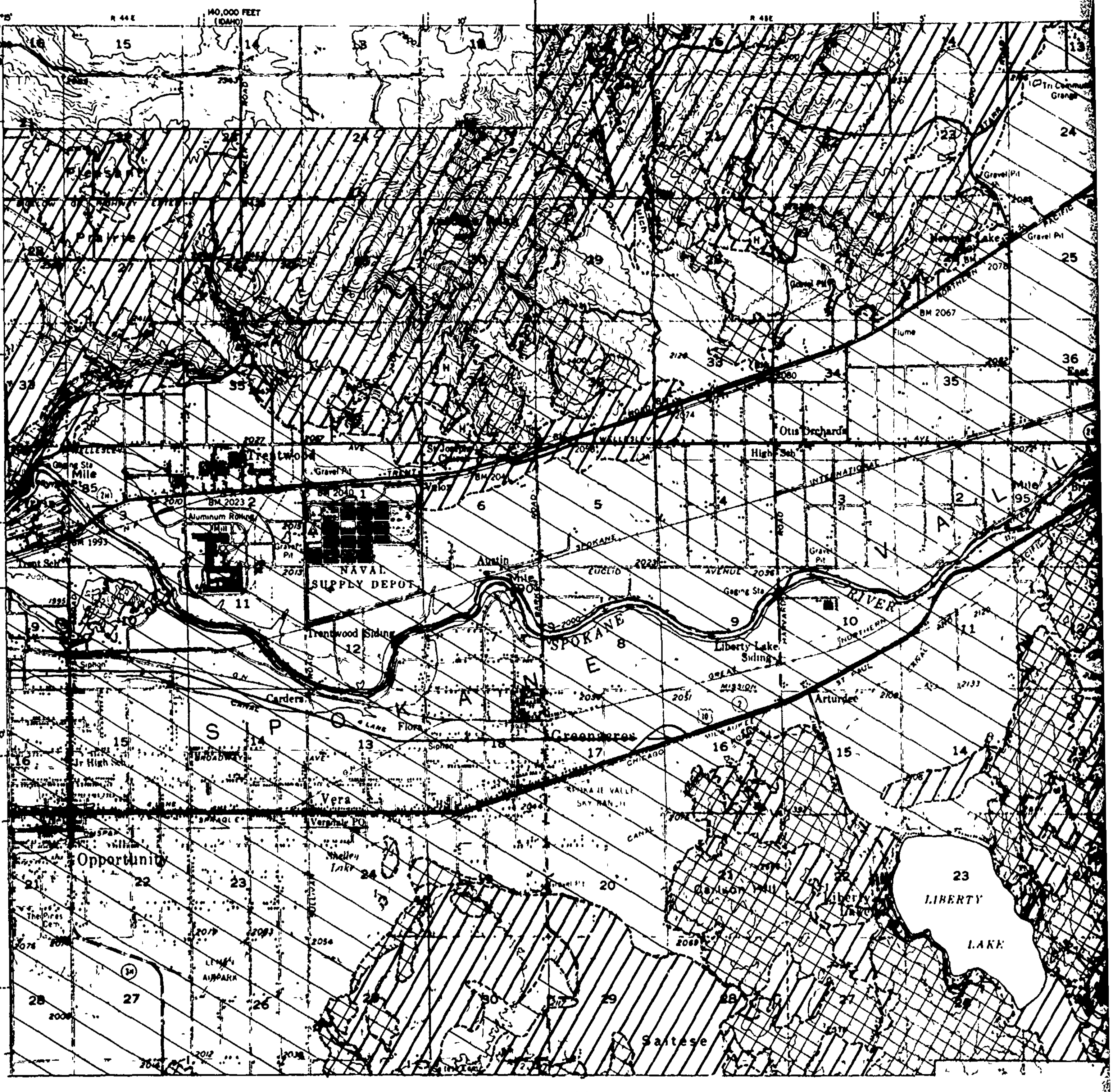
U S ARMY
ENGINEER DISTRICT SEATTLE
CORPS OF ENGINEERS
SEATTLE WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

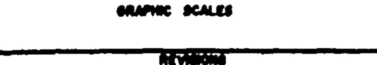
SURFACE PERMEABILITY
AREA 22

DACW67-73-C-0096

PLATE 303-16



MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949



GRAPHIC SCALES

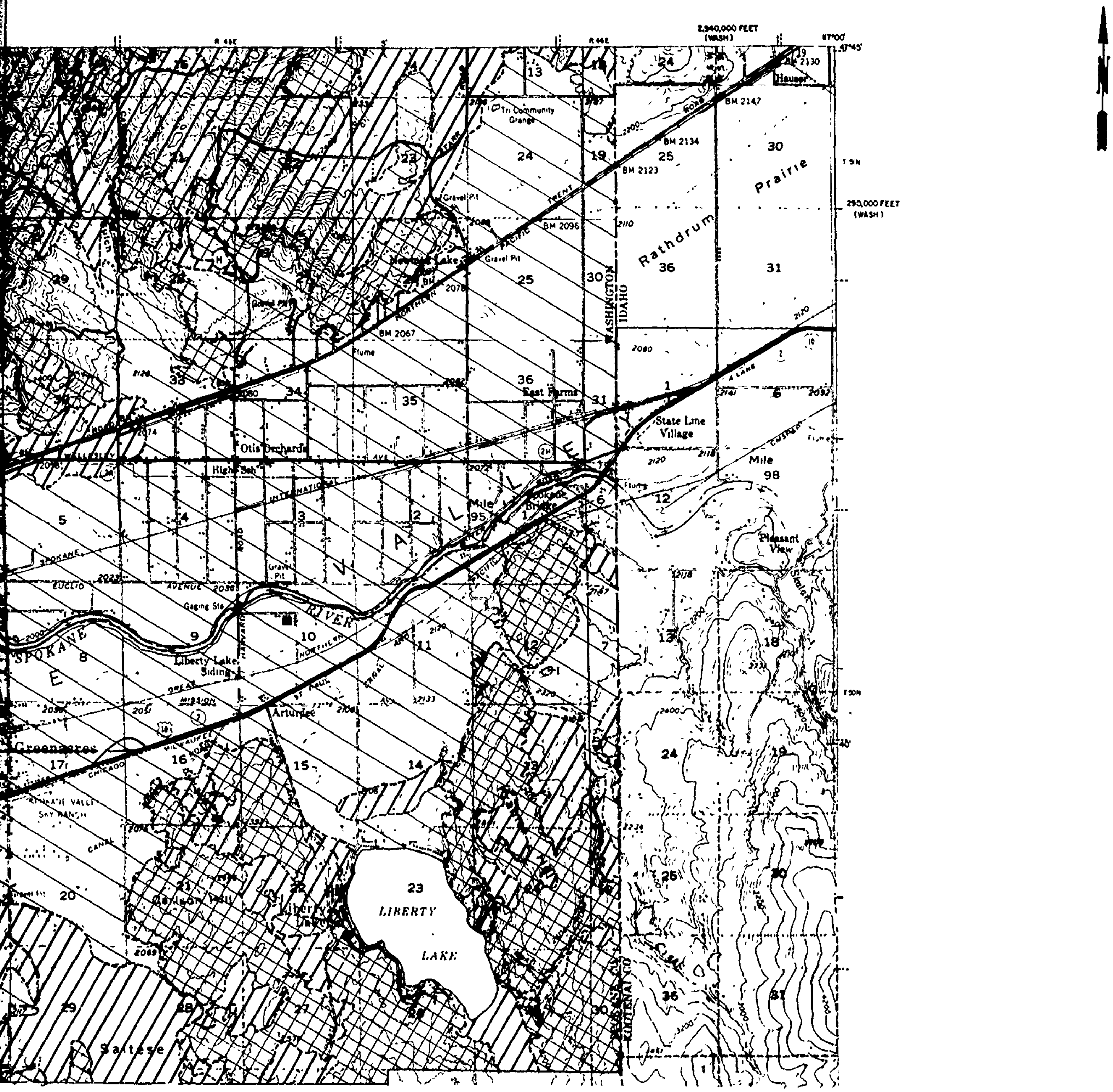
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, A[illegible] Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represe[illegible] relative permeability of the [illegible] soils within about 3 feet of th[illegible] ground surface



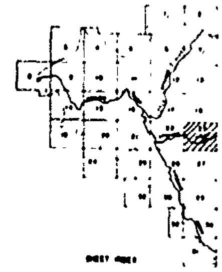
MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, A[illegible] Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

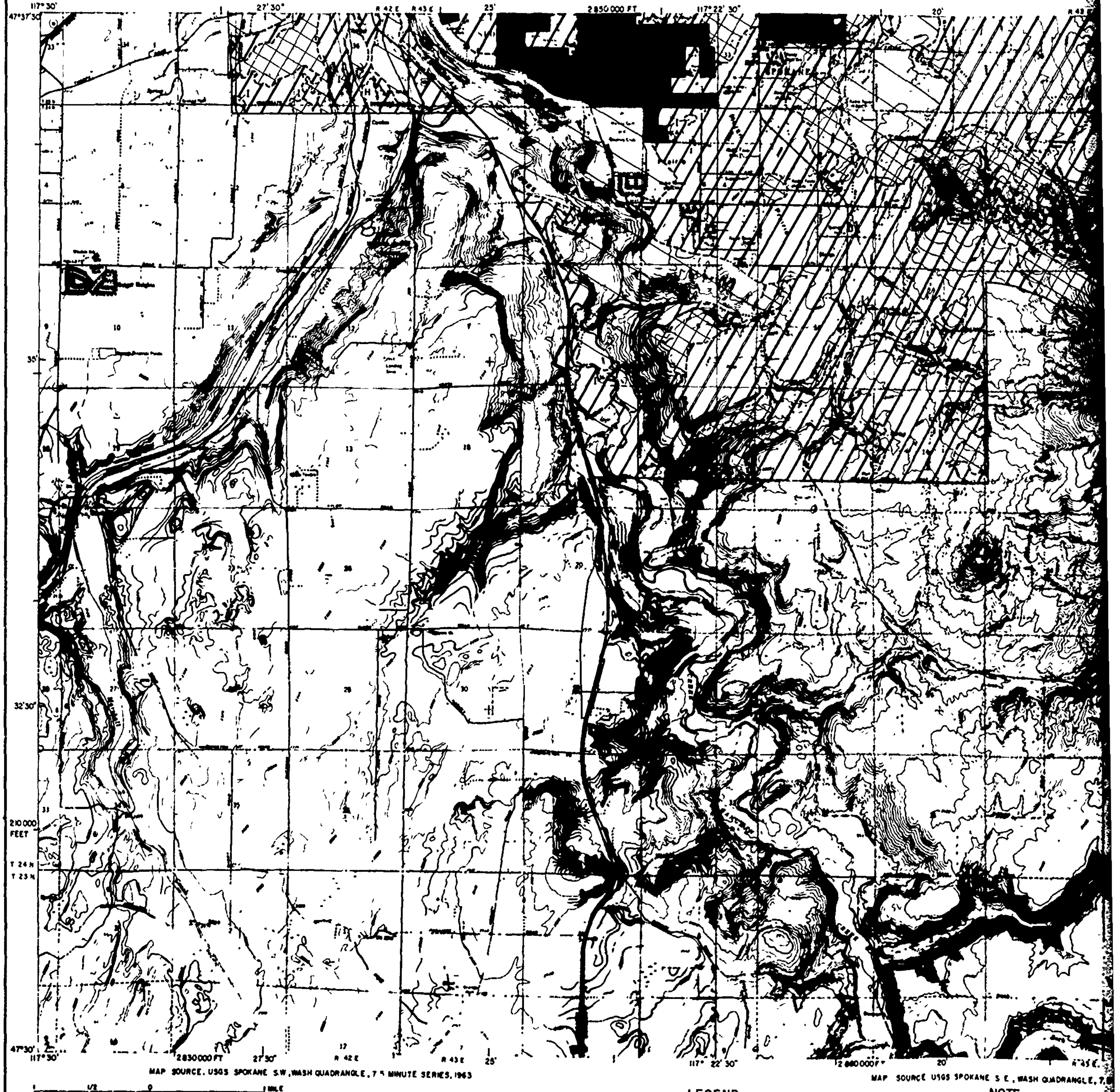
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

SURFACE PERMEABILITY
AREA 23

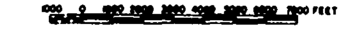
DACW67-73-C-0096

PLATE 303-17



MAP SOURCE. USGS SPOKANE S.W., WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE S.E., WASH QUADRANGLE, 7.5



GRAPHIC SCALES

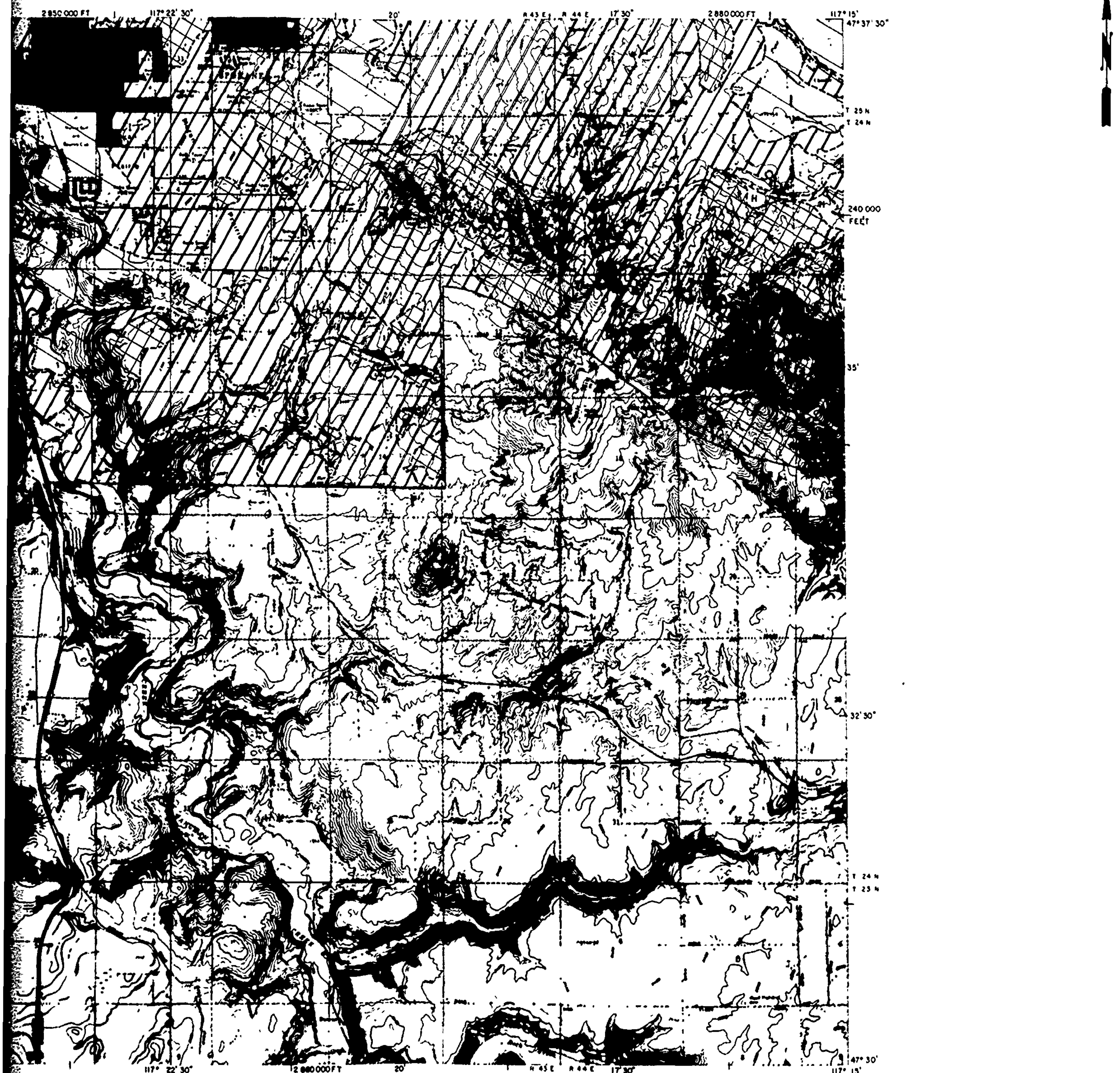
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{6}$	Very fine sands, silty sands and gravels, silts	Wm Am Lm Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface



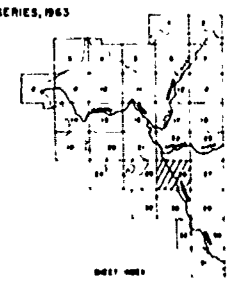
MAP SOURCE: USGS SPOKANE S E, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm Am Lm Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

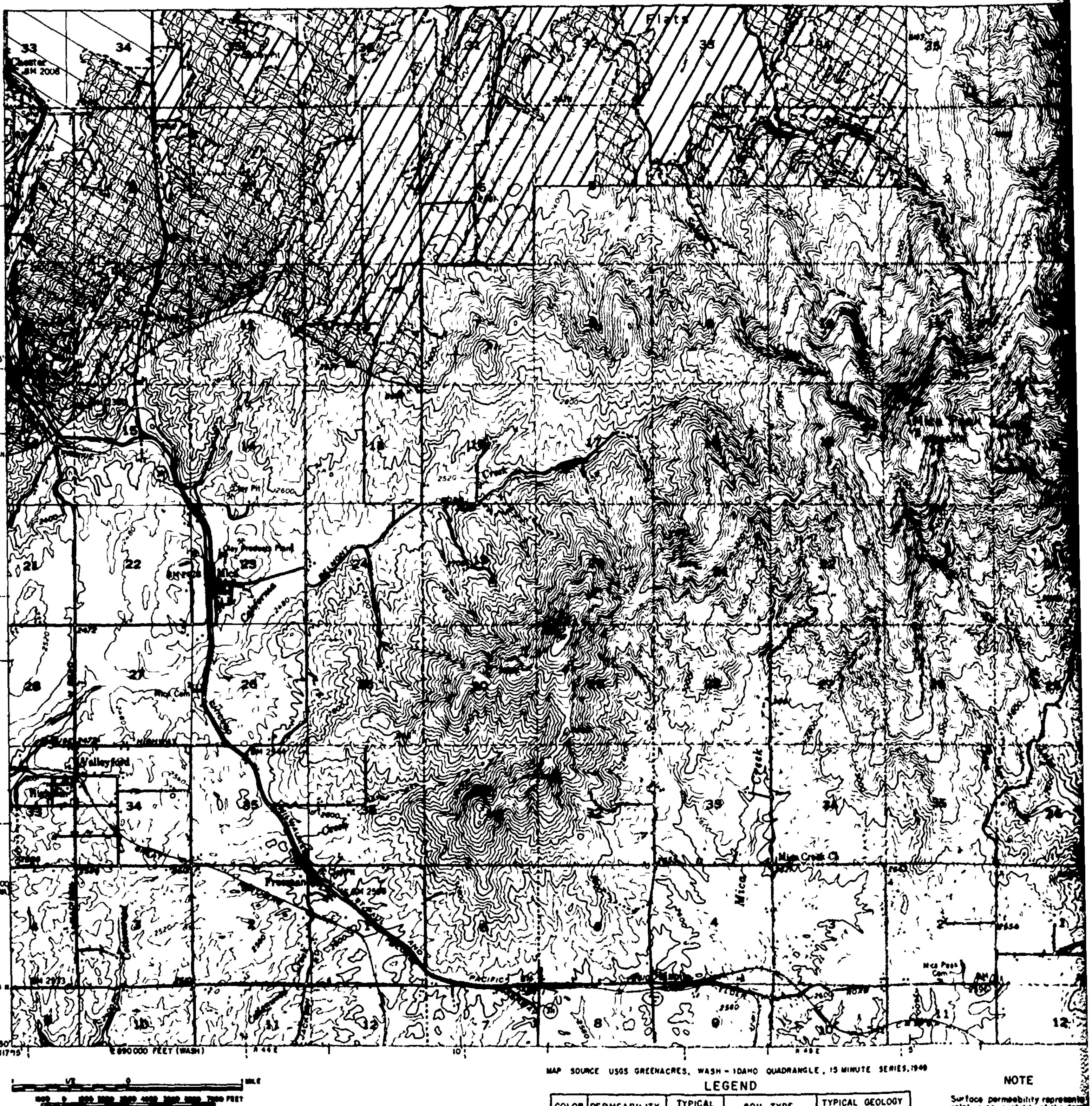
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

SURFACE PERMEABILITY
AREA 26

DACW67-73-C-0096

PLATE 303-18



MAP SOURCE USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

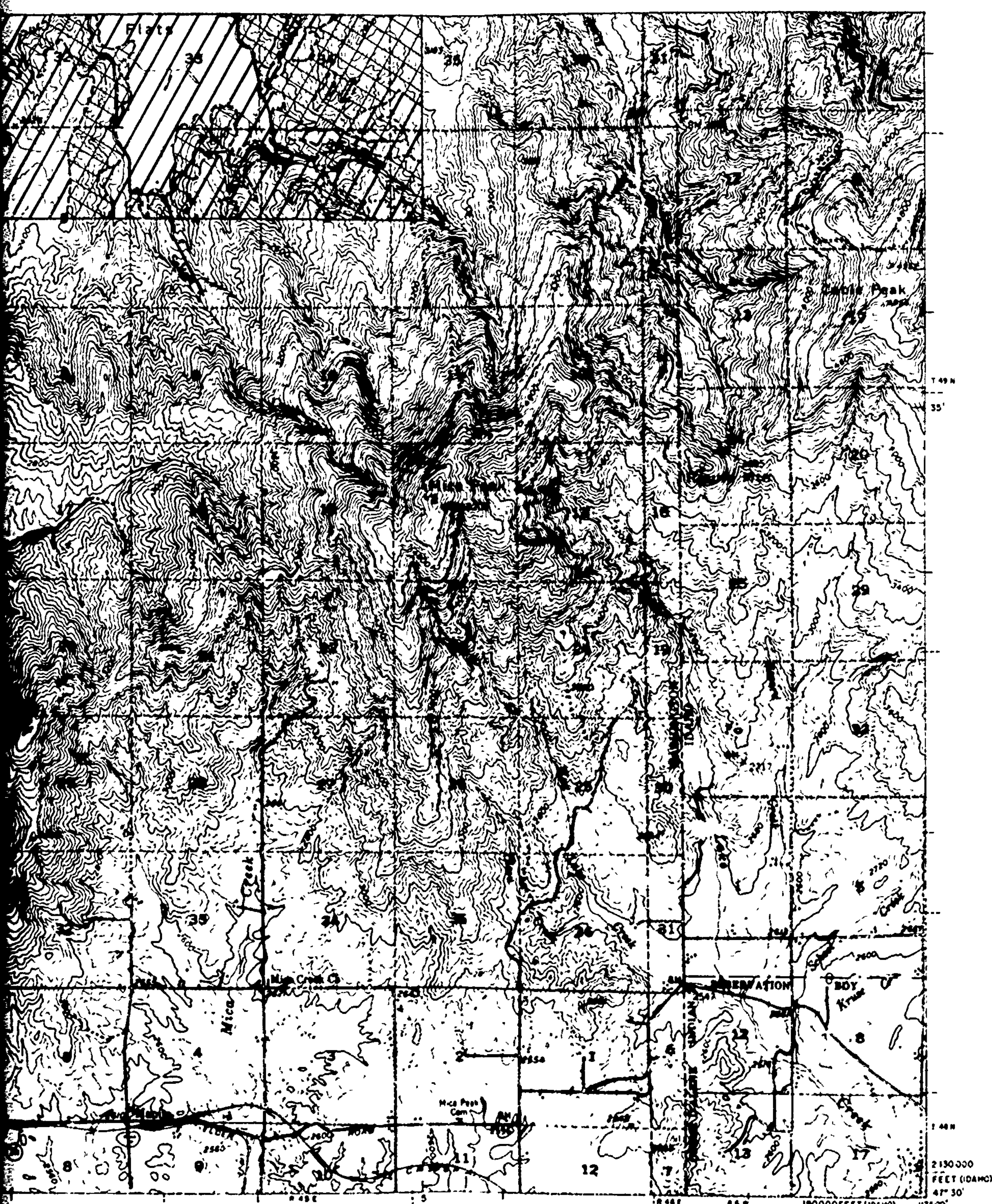
COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents relative permeability of the dom soils within about 3 feet of the ground surface

REVISIONS

SYMBOL	DESCRIPTION	DATE	BY



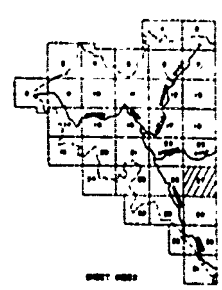
MAP SOURCE. USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	>10⁻⁴	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Ge, Rs, Ws
L	Low	>10⁻⁴-10⁻⁶	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	>10⁻⁶	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Surface permeability represents the relative permeability of the dominant soils within about 3 feet of the ground surface

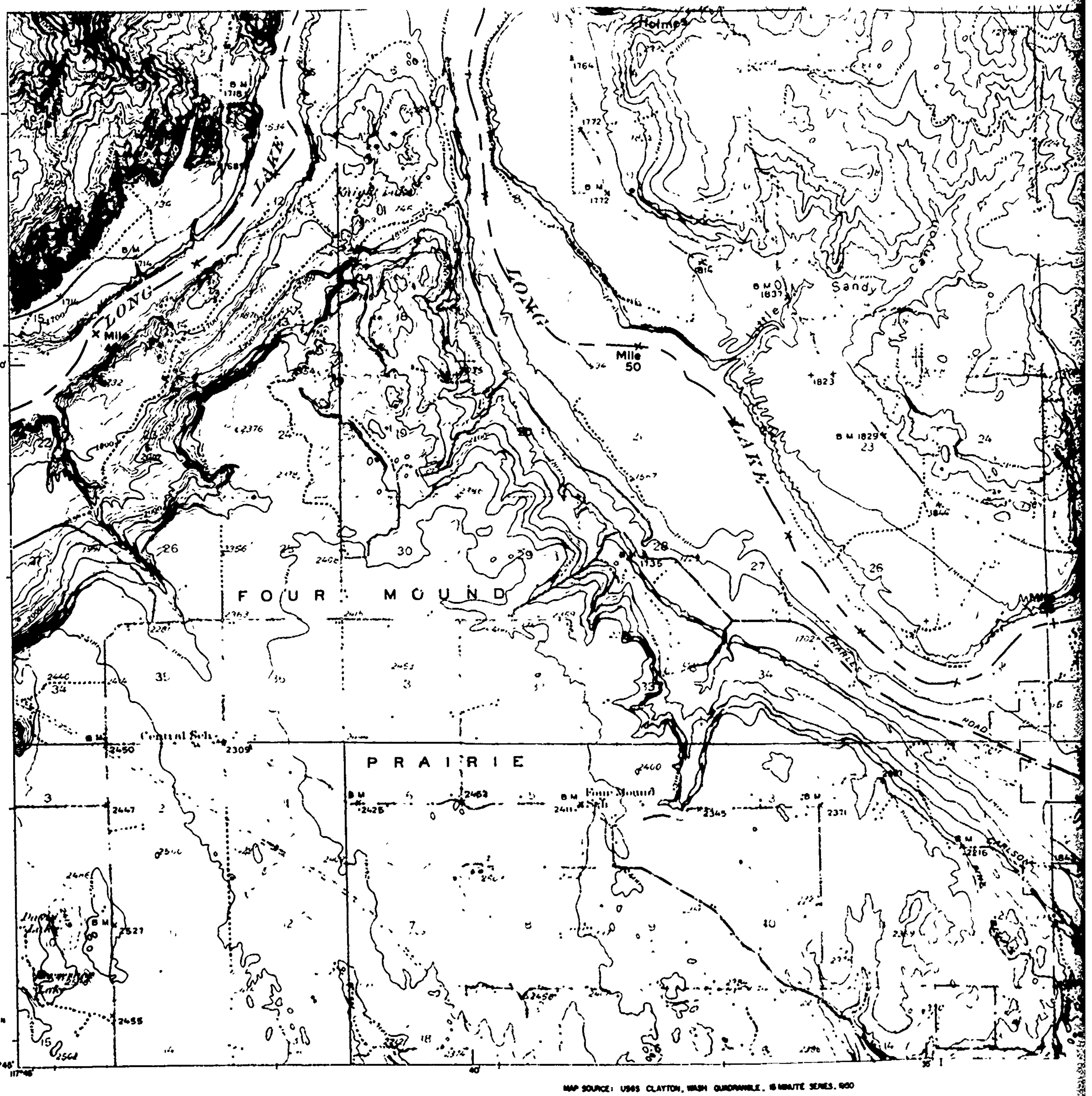


WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

SURFACE PERMEABILITY

AREA 27

PLATE 303-19



MAP SOURCE: USGS CLAYTON, WASH QUADRANGLE, 15 MINUTE SERIES, 1950

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

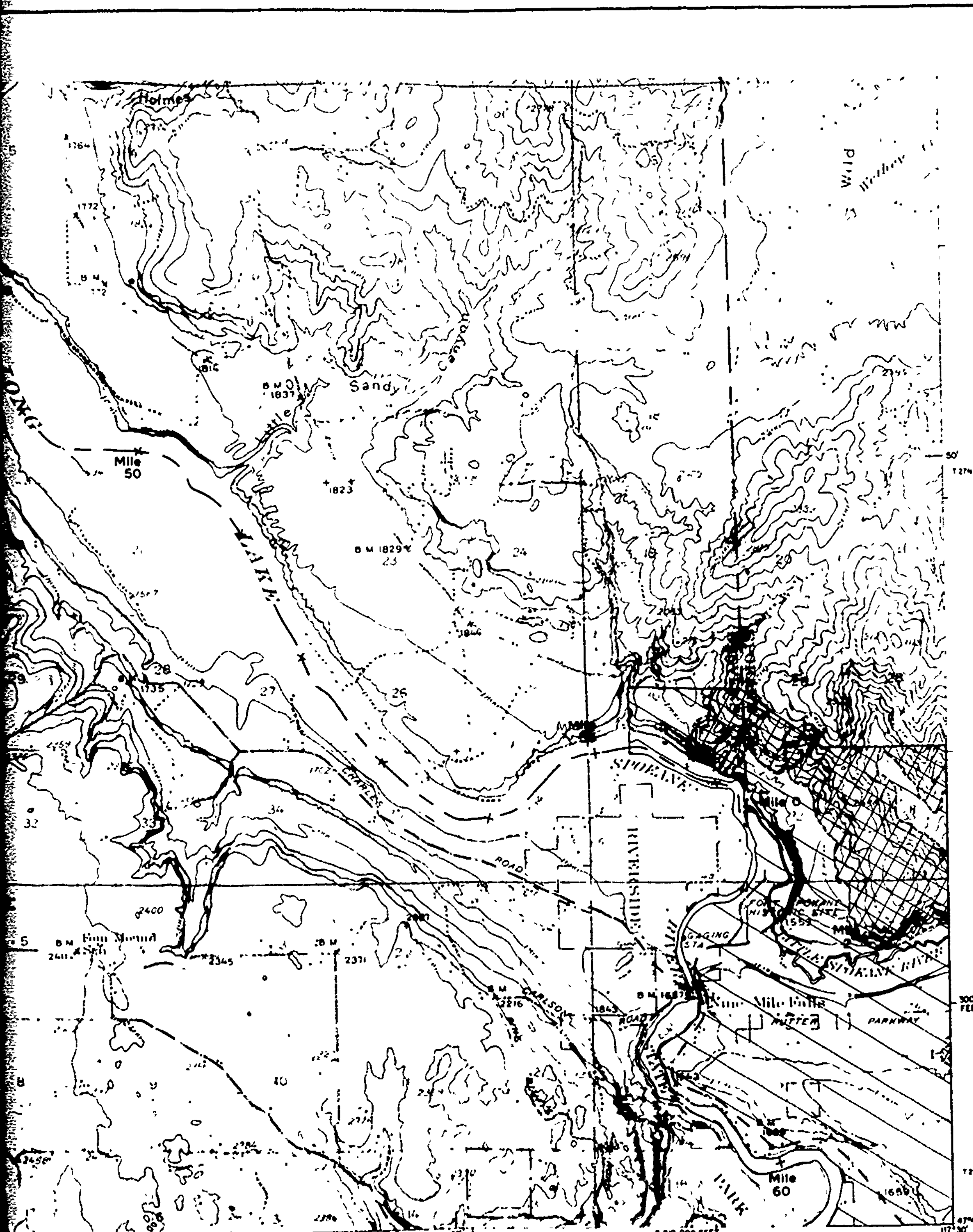
LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}$ 10^{-6}	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represe[nts] the relative permeability of the [...] soils from about 3 feet to 5 feet b[...] the ground surface

REVISIONS			
	DESCRIPTION	DATE	BY



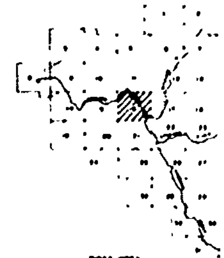
MAP SOURCE USGS CLAYTON, WASH QUADRANGLE, 15 MINUTE SERIES, 1950

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}$ 10^{-6}	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

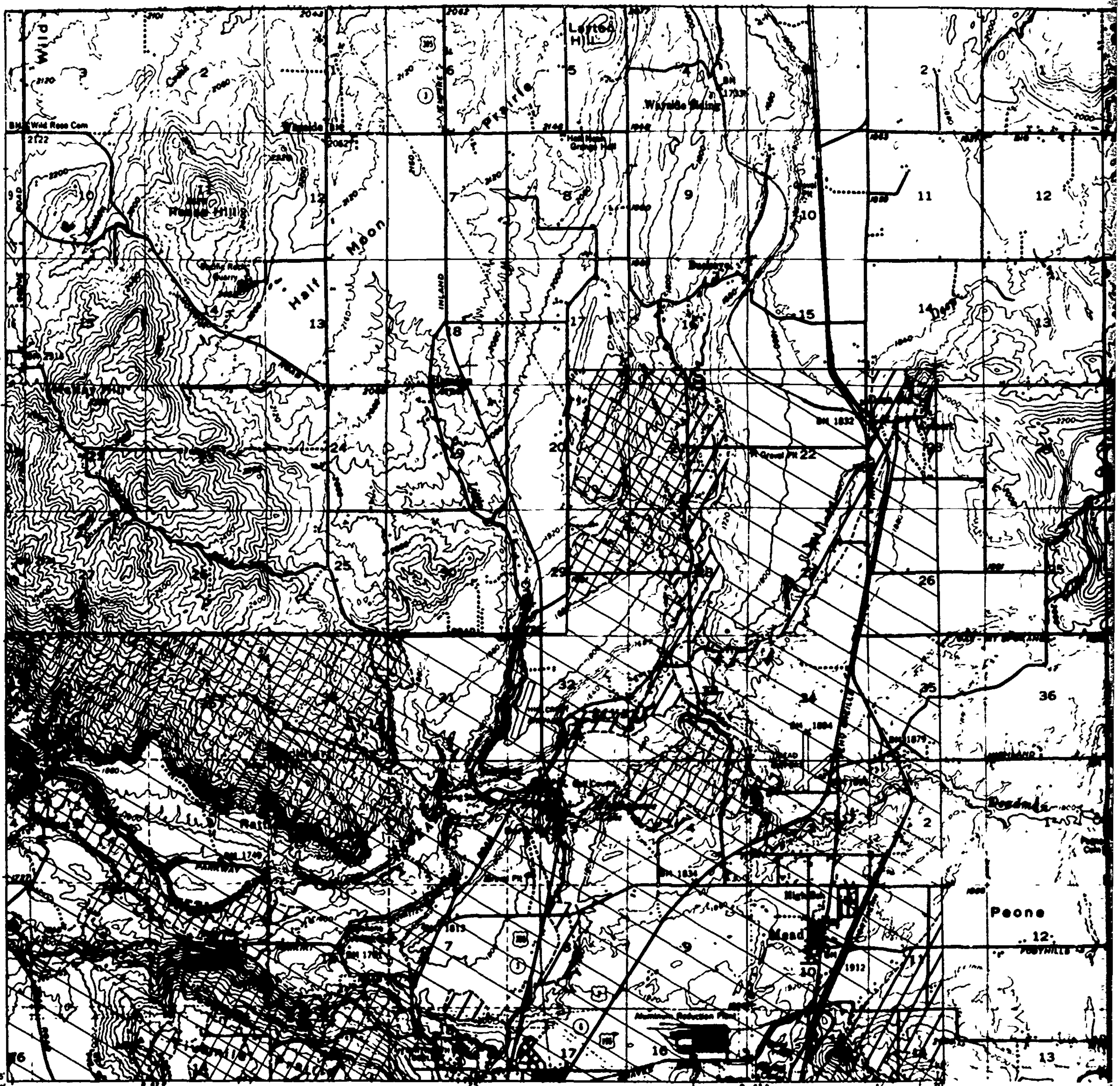
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY AREA 16

DACW67-73-C-0090

PLATE 303-20



MAP SOURCE. USGS DEER PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

GRAPHIC SCALES

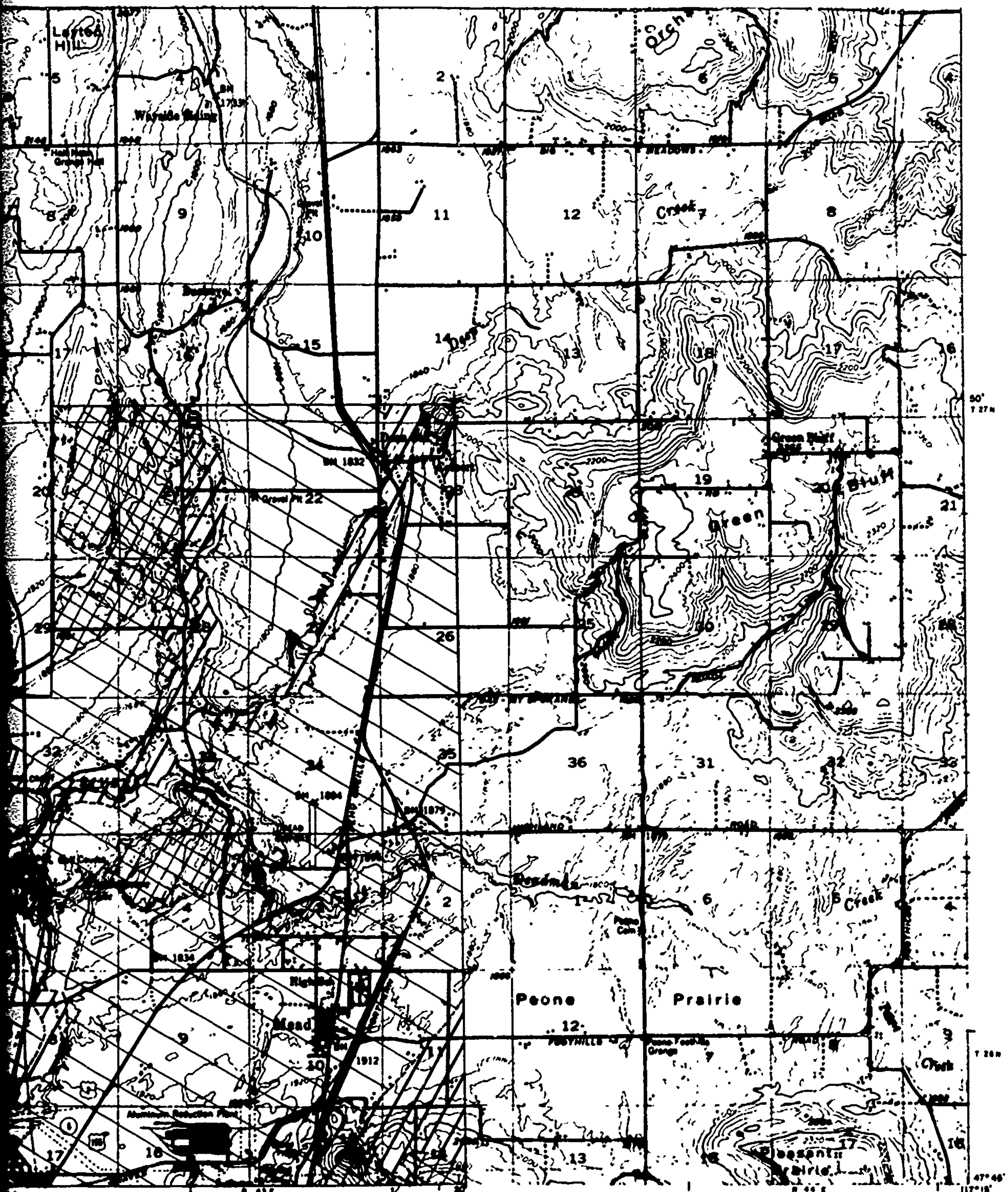
REVISIONS			
	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability re[illegible] the relative permeability of [illegible] soils from about 3 feet to 5 [illegible] the ground surface



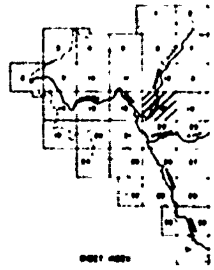
MAP SOURCE: USGS DEER PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface.



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

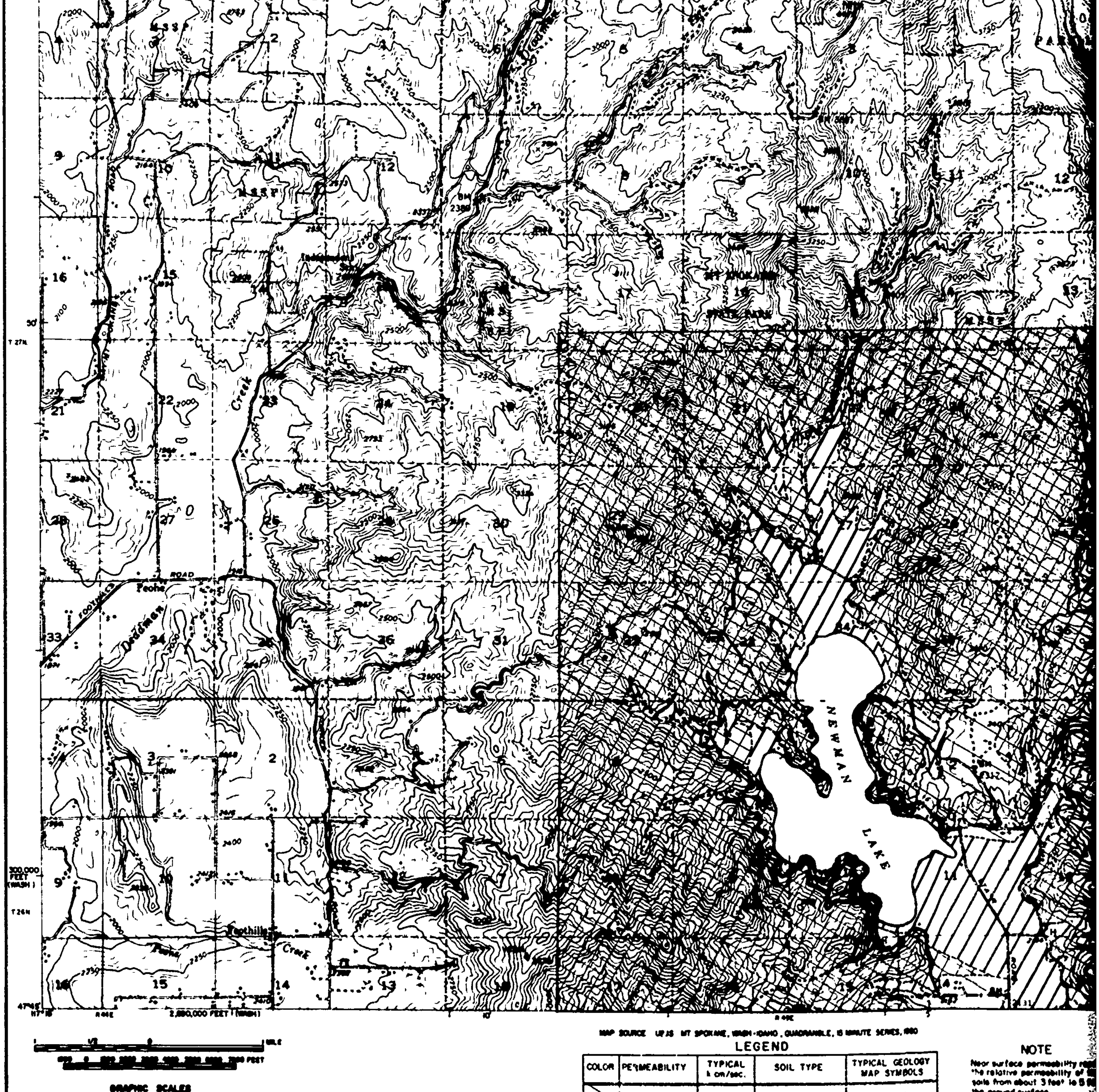
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY AREA 17

DACW67-73-C-0090

PLATE 303-21



MAP SOURCE USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1950

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec.	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gs, As, Ls, Cs/g, Gs, Fs, Ws
L	Low	$>10^{-4}$-10^{-6}	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

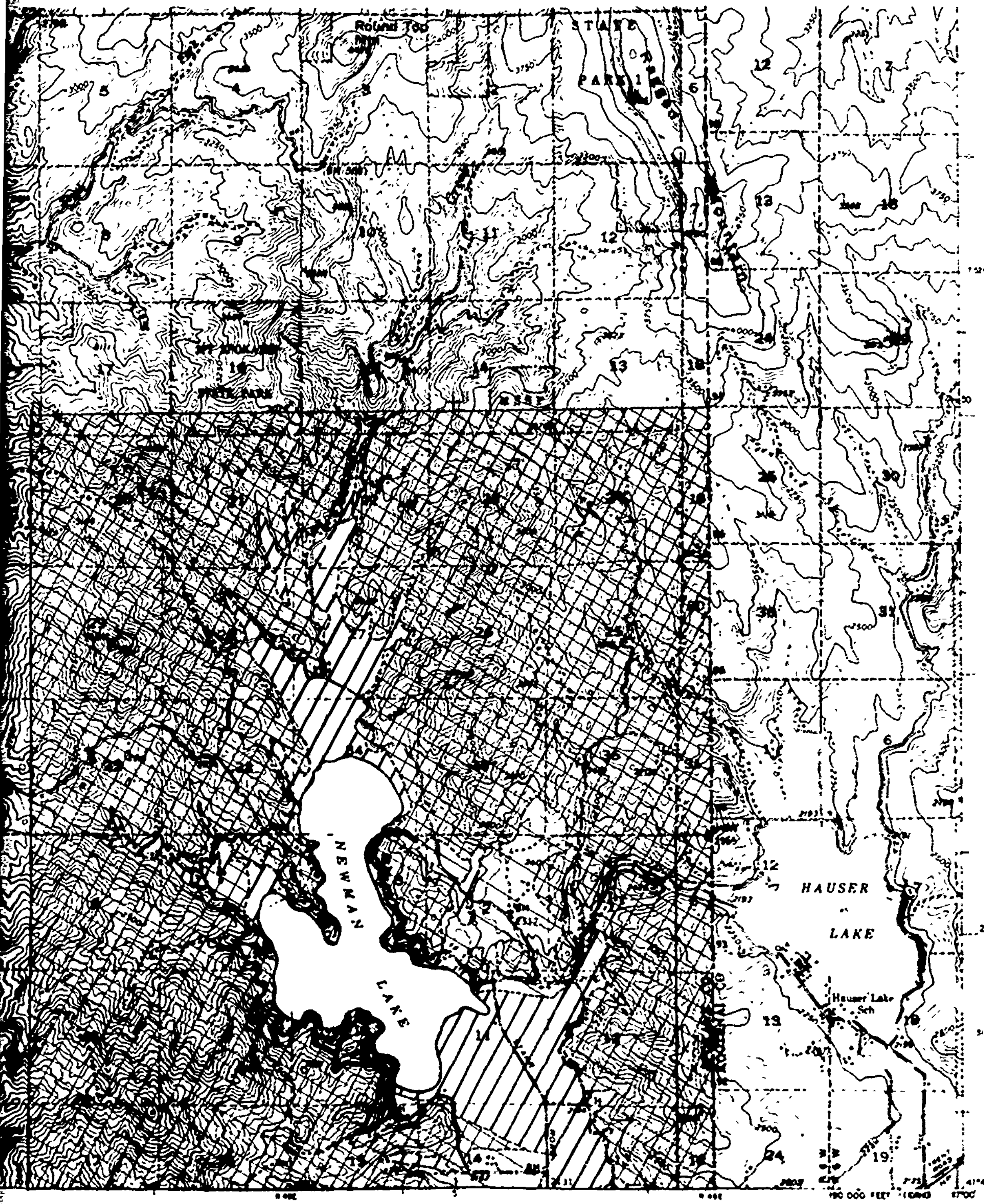
Near surface permeability r[illegible] the relative permeability of [illegible] soils from about 3 feet to 5 [illegible] the ground surface

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



MAP SOURCE: USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1960

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gs, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}$-10^{-6}	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

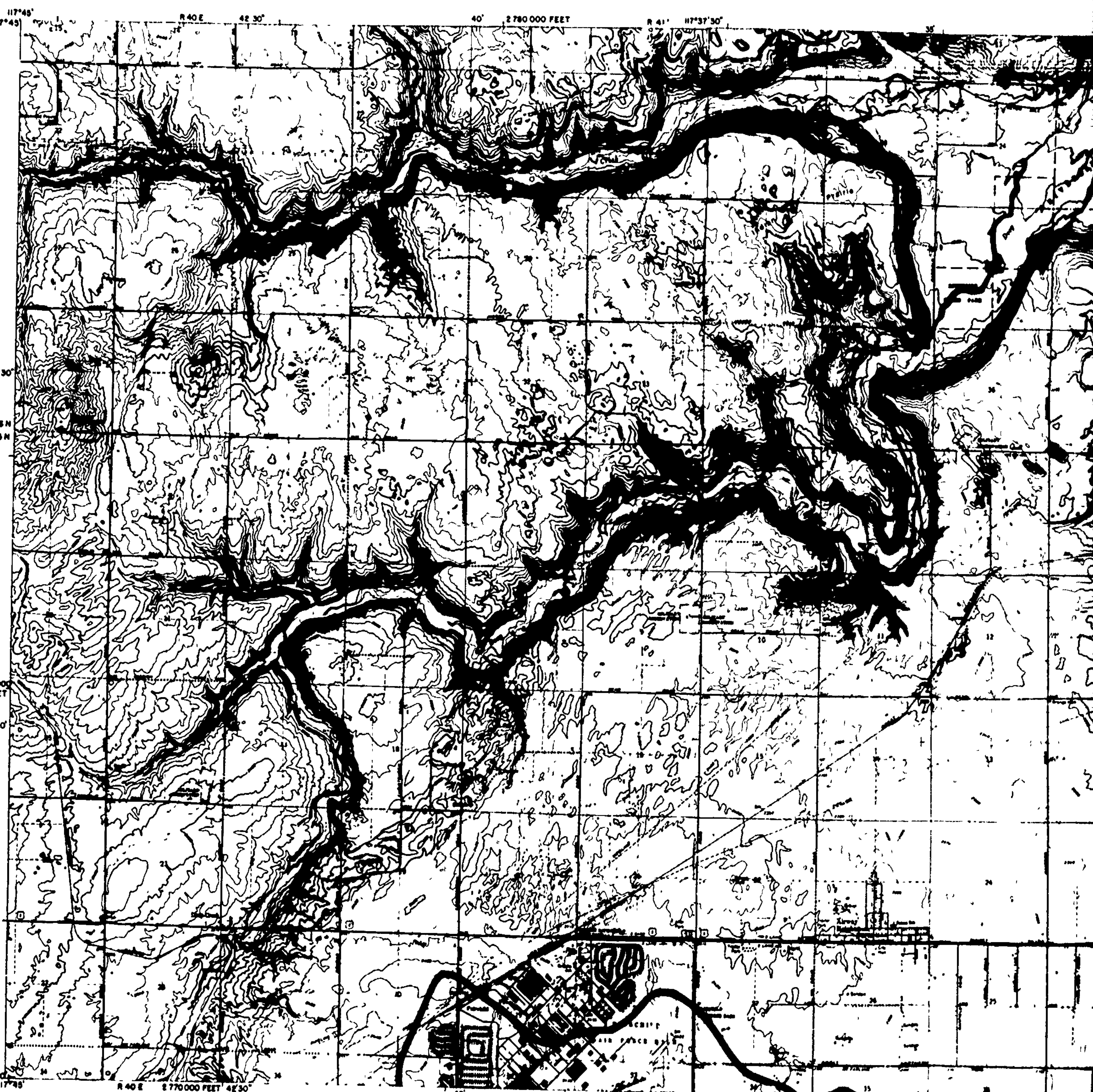
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY AREA 18

DACW67-73-C-0090

PLATE 303-22



MAP SOURCE: USGS DEEP CREEK, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE: USGS AIRWAY HEIGHTS WASH QUAD

GRAPHIC SCALES

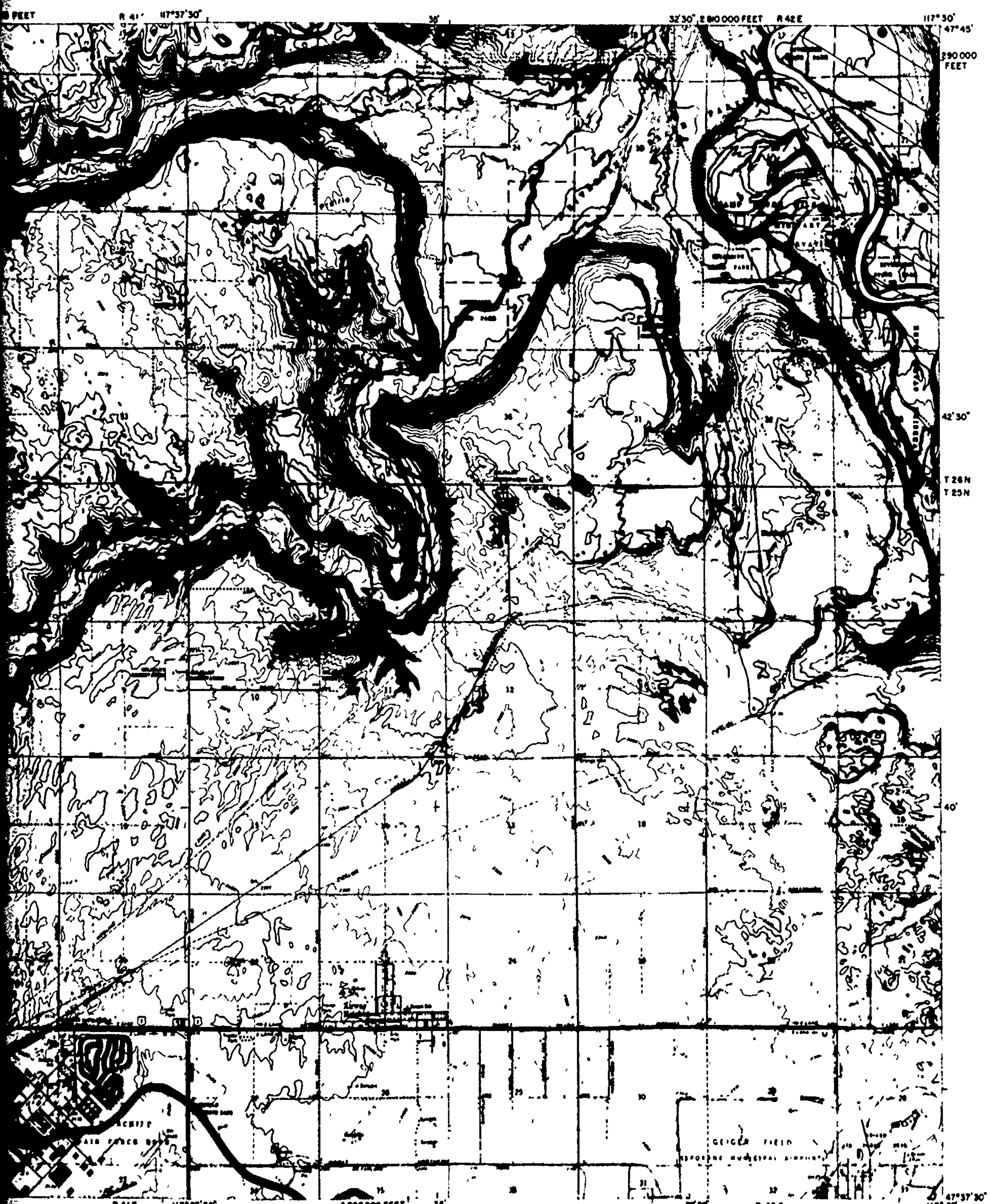
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically Impervious	$>10^{-6}$	Rock, clayey s. s	BA, ST, Am, Lm

NOTE

Near surface permeability repr the relative permeability of th soils from about 3 feet to 5 fe the ground surface



SERIES, 1963

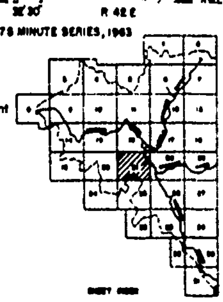
MAP SOURCE USGS AIRWAY HEIGHTS WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

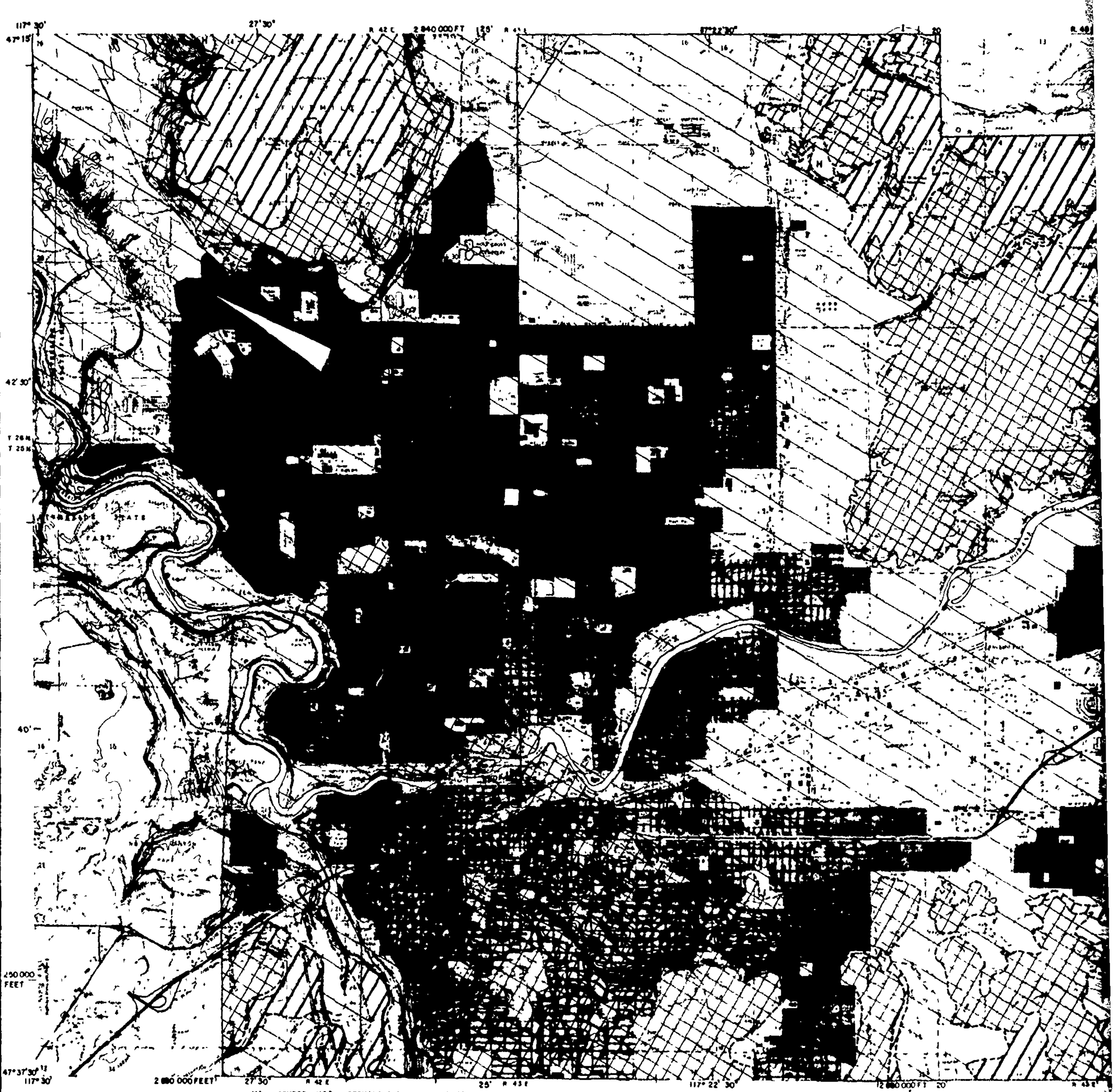
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY AREA 21

DACW67-73-C-0006

PLATE 303-23



MAP SOURCE USGS SPOKANE N.W., WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE N.E., WASH.

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

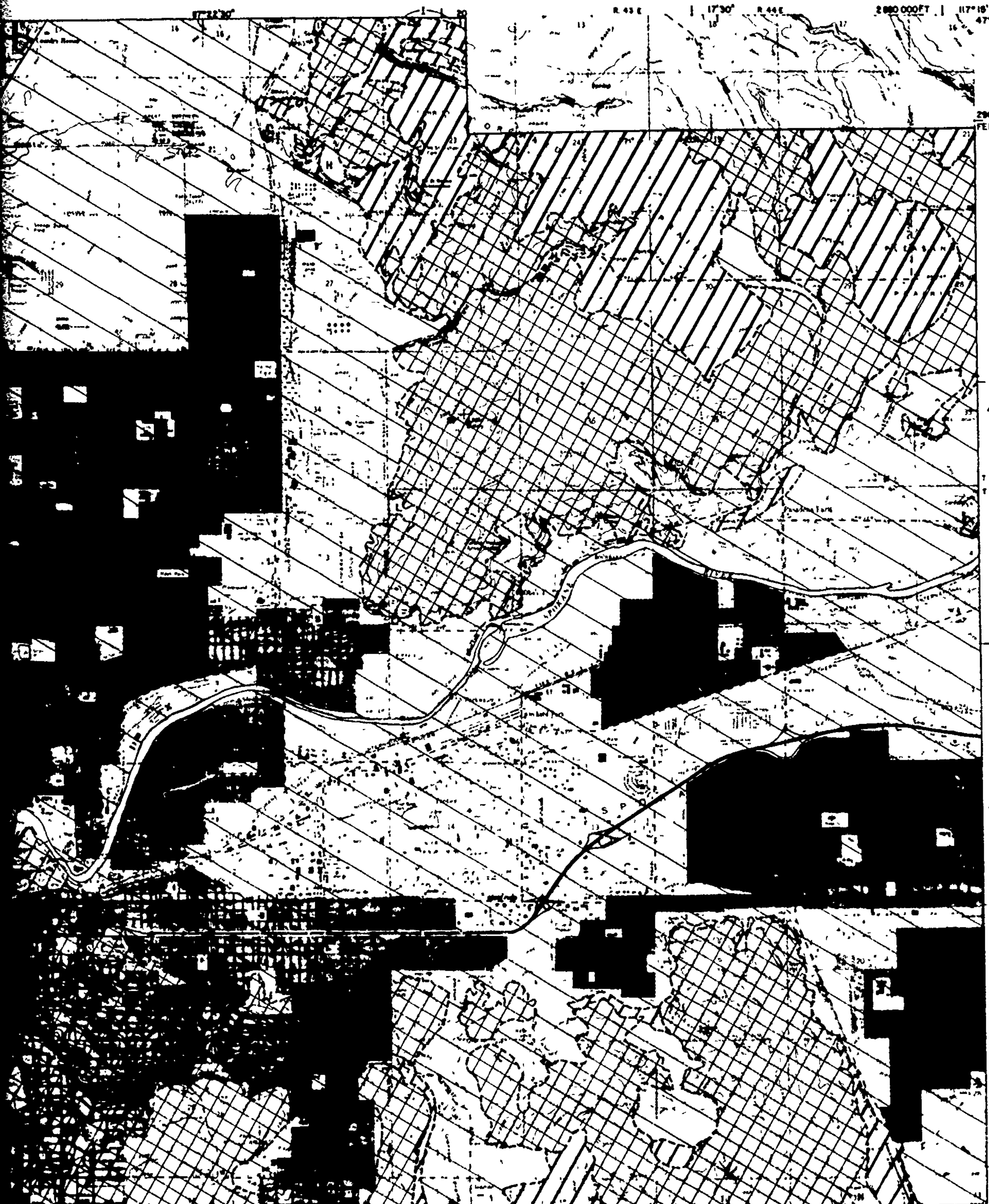
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am Lm

NOTE

Near surface permeability r
the relative permeability of
soils from about 3 feet to 5
the ground surface



SERIES, 1963

MAP SOURCE USGS SPOKANE N E, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g, Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface

KENNEDY TUDOR
CONSULTING ENGINEERS
SEATTLE WASHINGTON

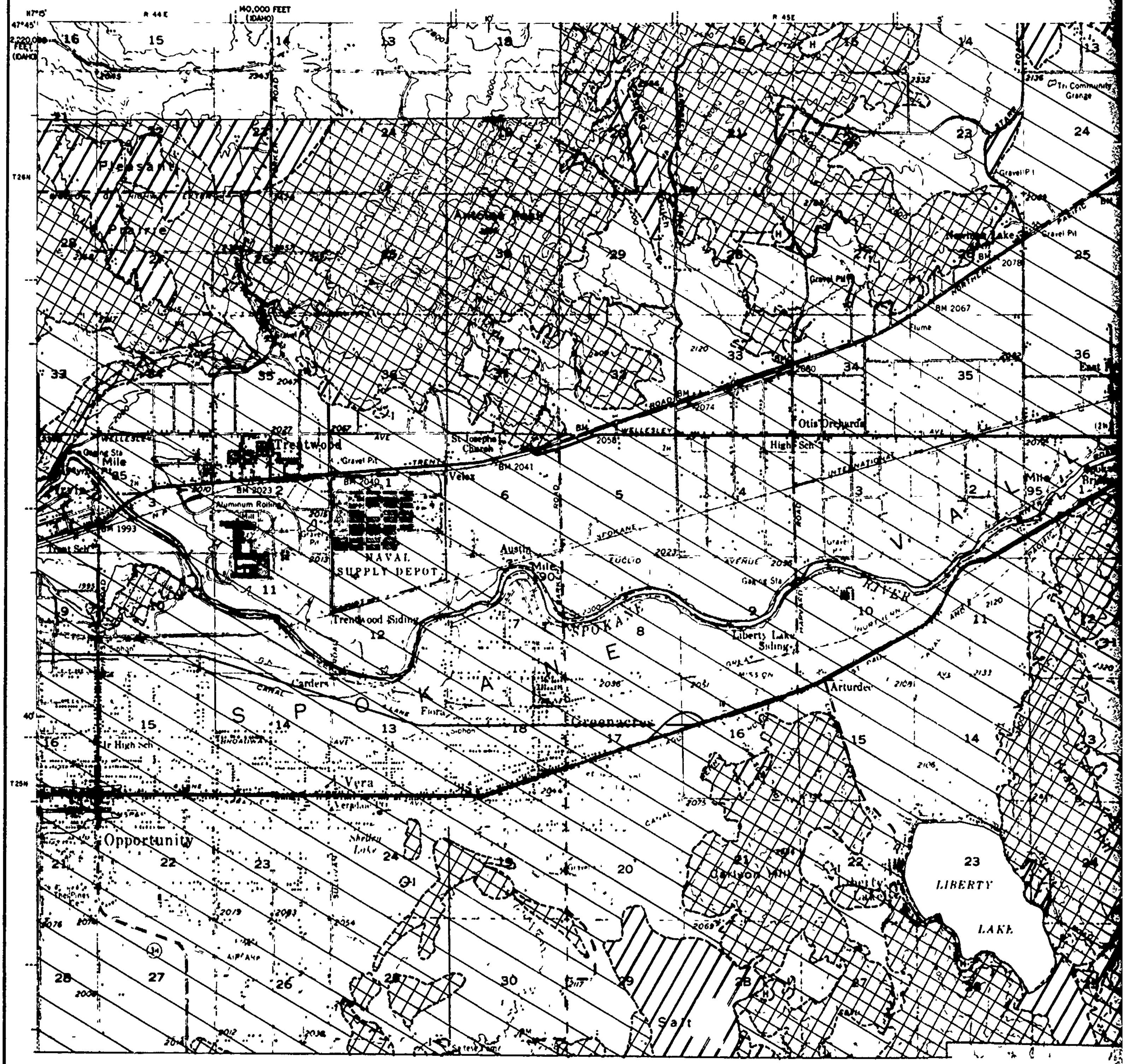
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY
AREA 22

DACW67 73-C-0096

PLATE 303-24



MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

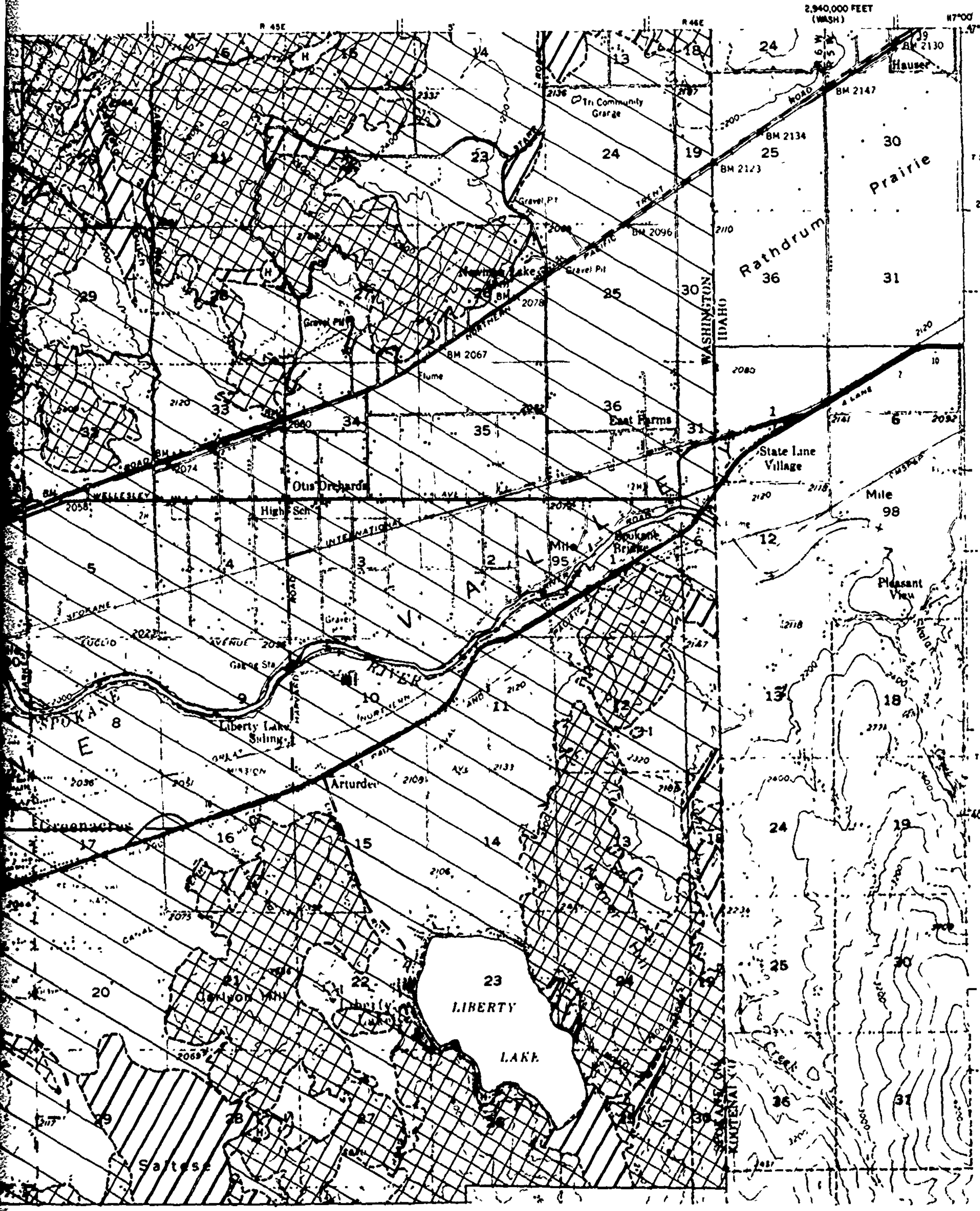
LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec.	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec.	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm, As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE WASHINGTON

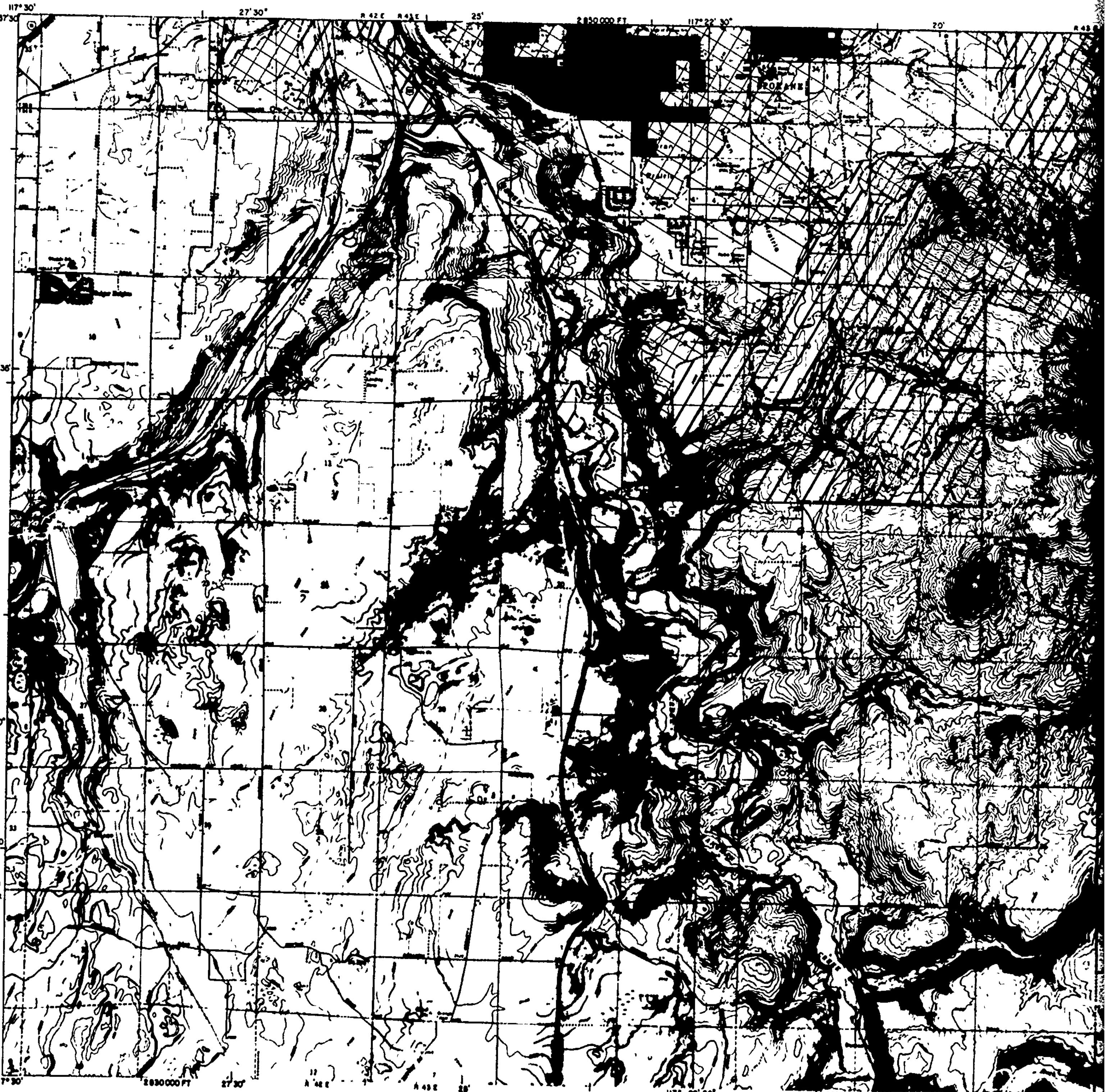
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY
AREA 23

DACW67-73-C-0096

PLATE 303-25



MAP SOURCE: USGS SPOKANE S.W., WASH. QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE S E , WASH QUADRANGLE, 7.5

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

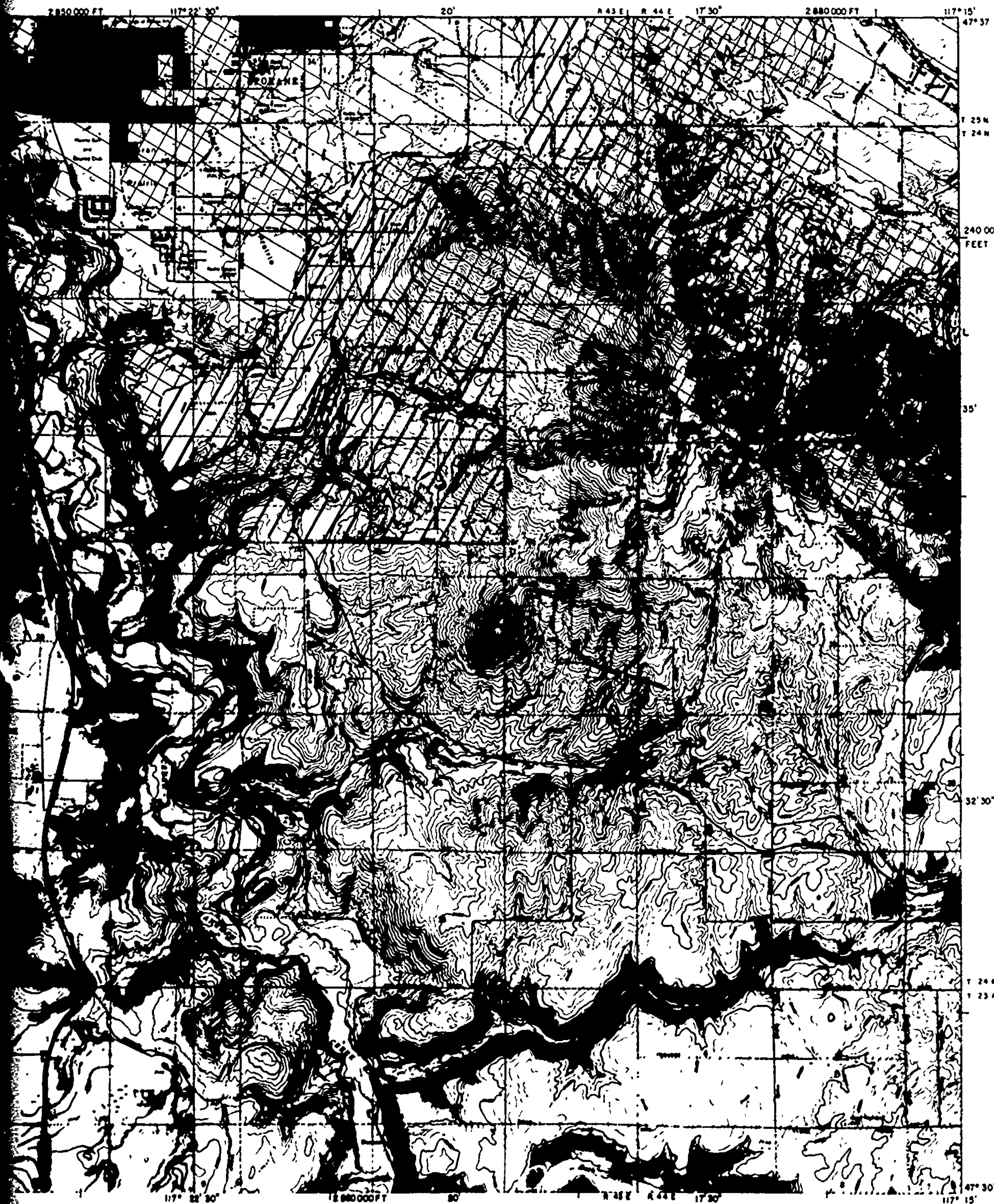
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface.



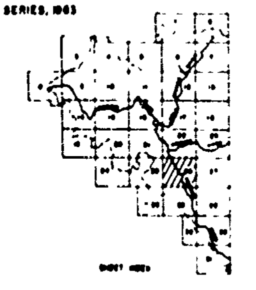
MAP SOURCE: USGS SPOKANE S E, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m, Cs/g/m
Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface.

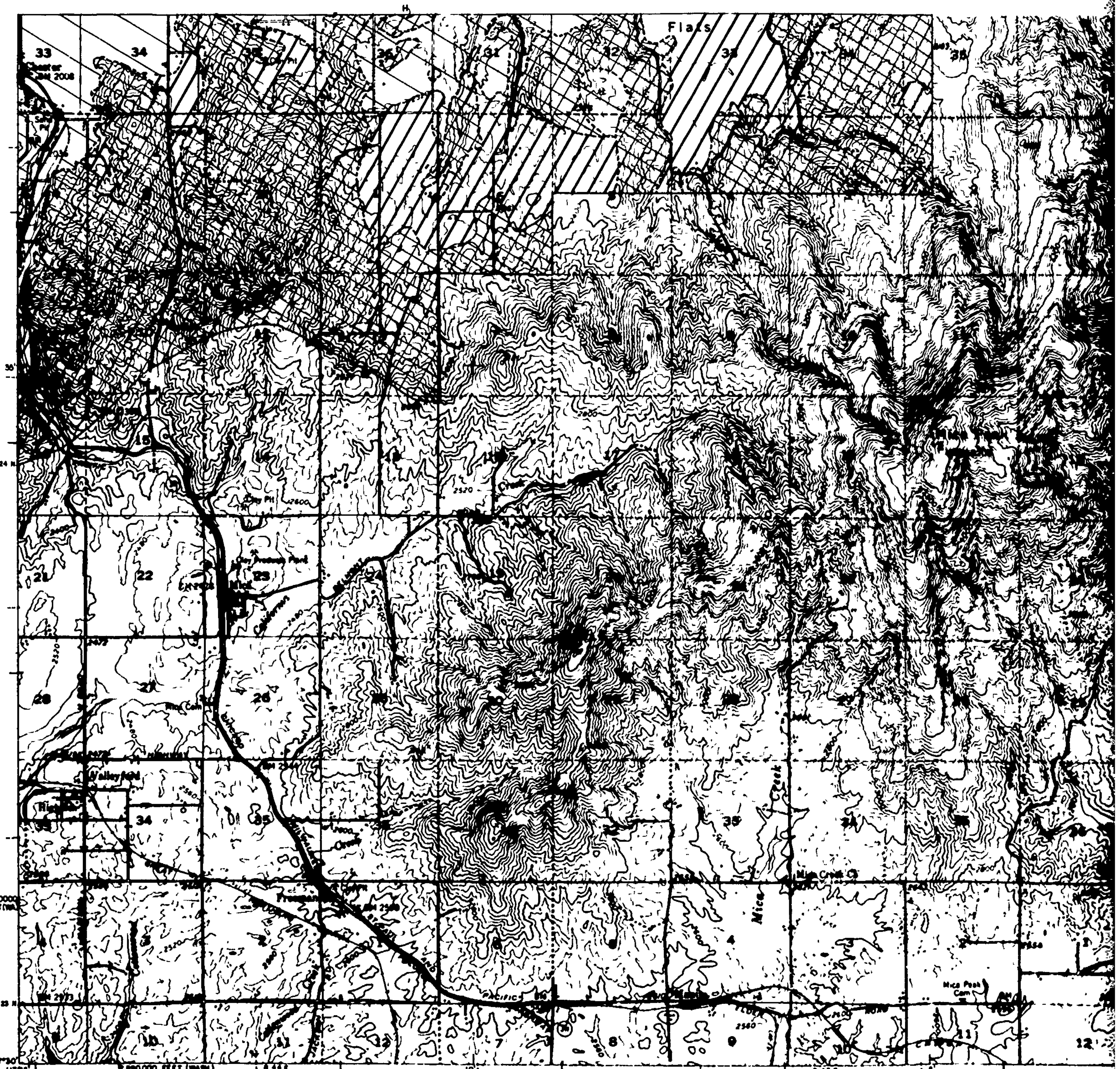


U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

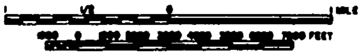
WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY AREA 26

PLATE 303-26



MAP SOURCE. USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949



GRAPHIC SCALES

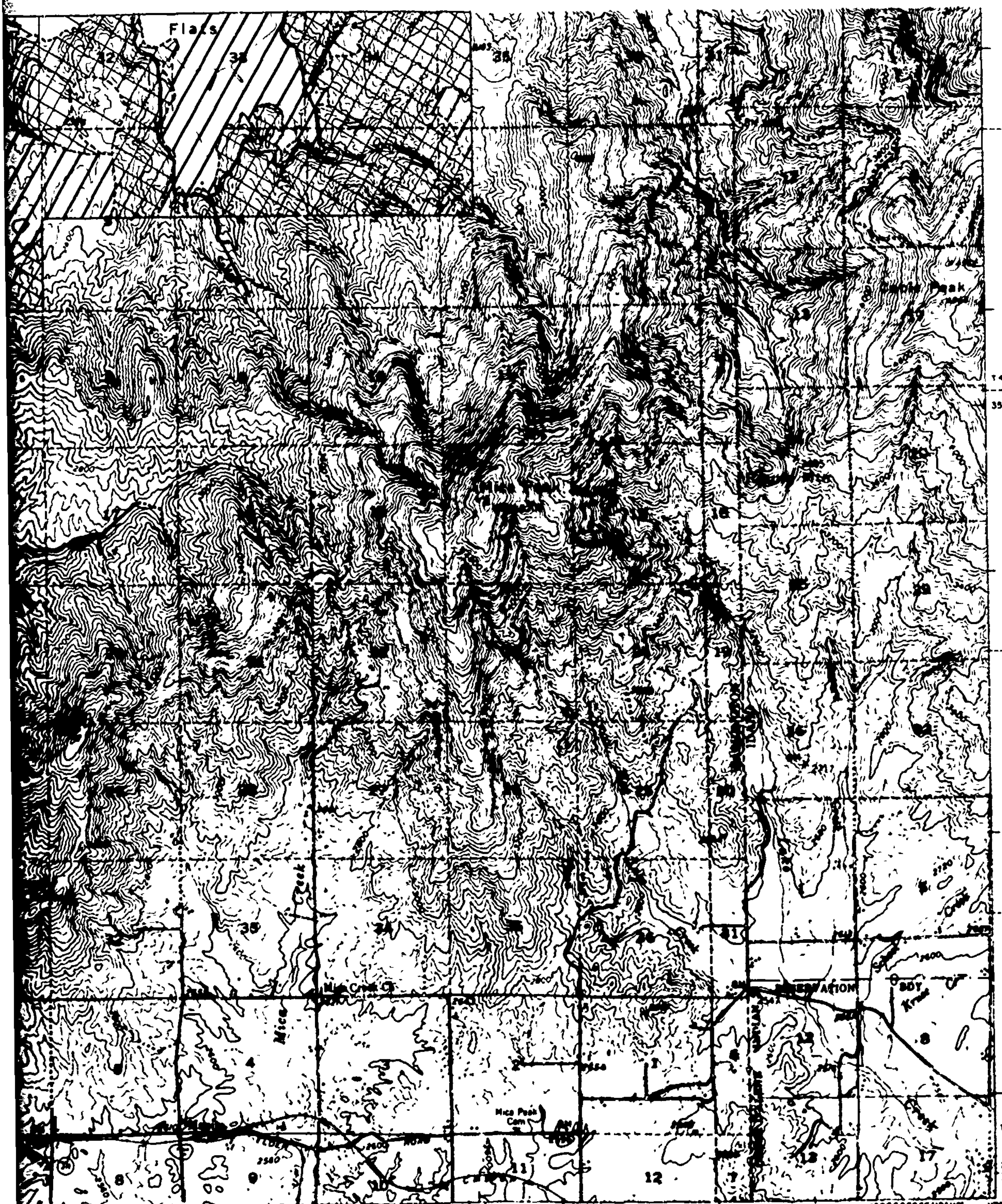
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m Cs/g/m
I	Practically impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability repre... the relative permeability of the ... soils from about 3 feet to 5 feet ... the ground surface



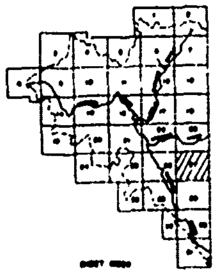
MAP SOURCE USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

COLOR	PERMEABILITY	TYPICAL k cm/sec	SOIL TYPE	TYPICAL GEOLOGY MAP SYMBOLS
H	High	$>10^{-4}$	Sands and Gravels relatively free of silt and clay	Gg, As, Ls, Cs/g Gs, Rs, Ws
L	Low	$>10^{-4}-10^{-6}$	Very fine sands, silty sands and gravels, silts	Wm, Am, Lm, Cm As/m, Ls/m, Gs/m, Rs/m Cs/g/m
I	Practically Impervious	$>10^{-6}$	Rock, clayey silts	BA, ST, Am, Lm

NOTE

Near surface permeability represents the relative permeability of the dominant soils from about 3 feet to 5 feet below the ground surface



KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

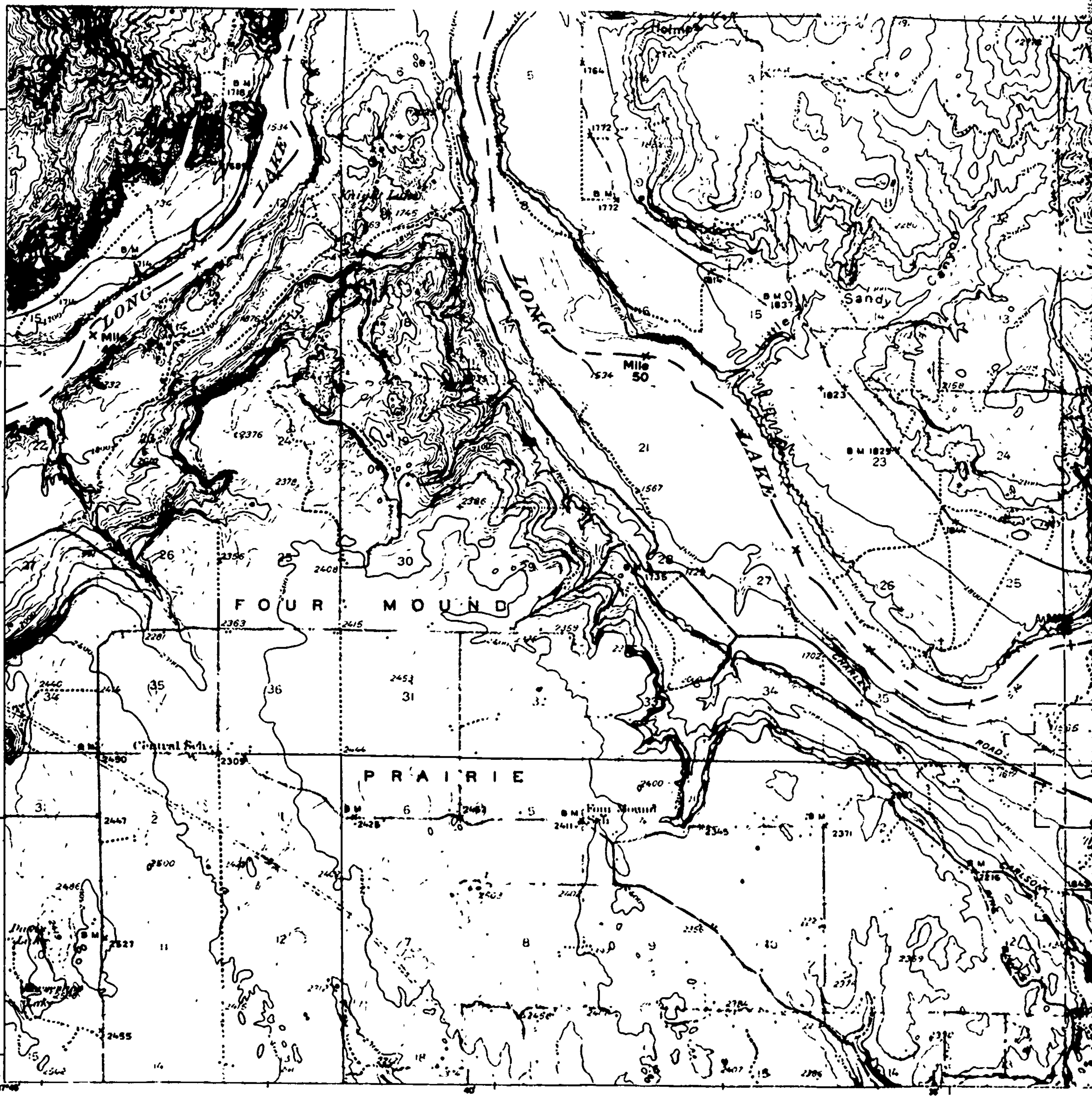
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

NEAR-SURFACE PERMEABILITY
AREA 27

DACW67-73-C-0000

PLATE 303-27



MAP SOURCE: USGS CLAYTON, WASH QUADRANGLE, 15 MINUTE SERIES, 1950

1 1/2 0 1 MILE

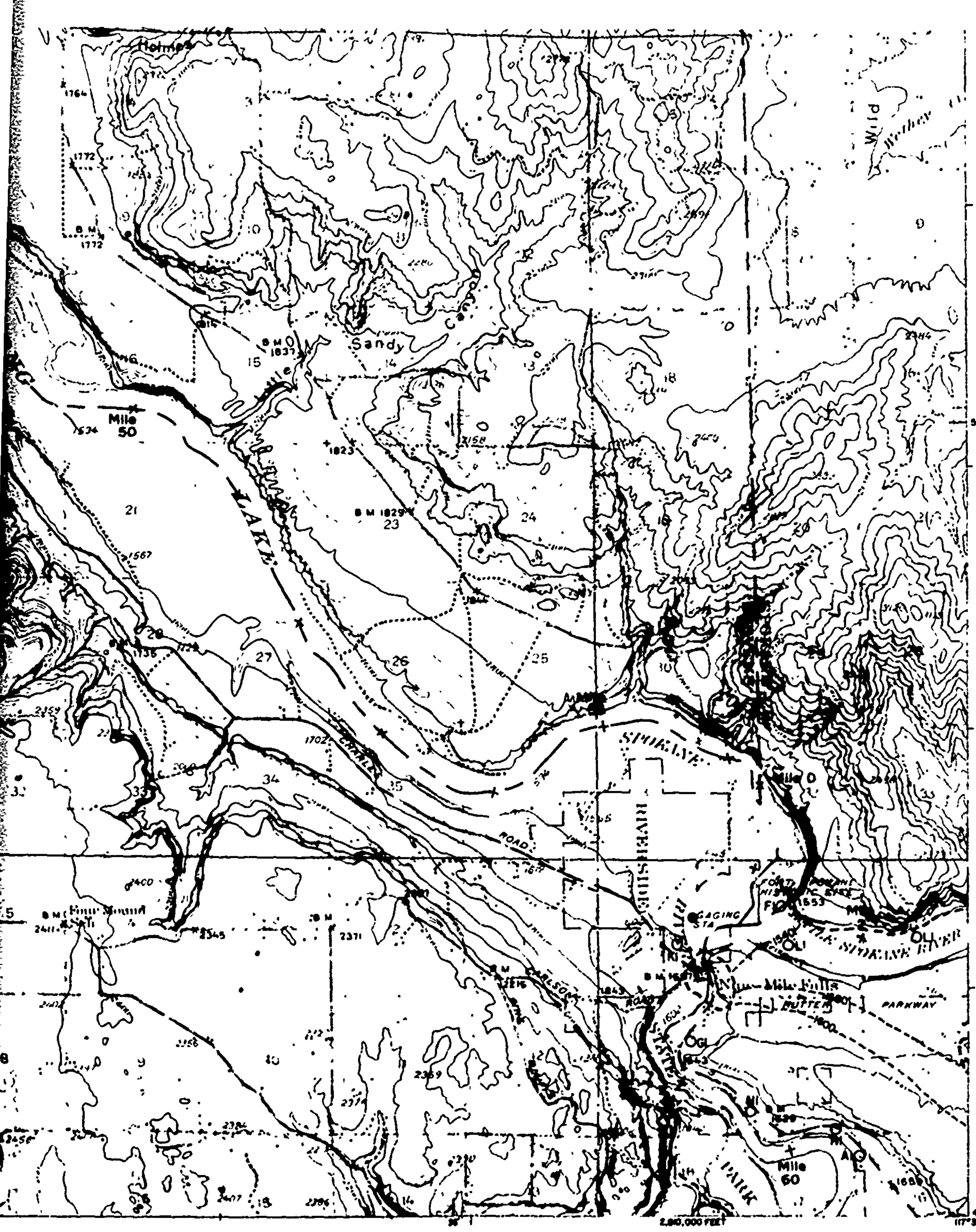
FEET

GRAPHIC SCALES

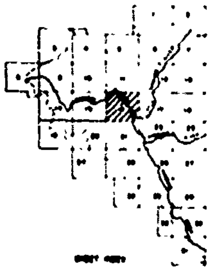
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifier boundary (approximate)
- 1610 Groundwater contour line with elevation dashed where inferred
- Seismic survey line – Newcomb 1953



MAP SOURCE: USGS CLAYTON, WASH. QUADRANGLE, 15 MINUTE SERIES, 1950



LEGEND

- ○ Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- ● Gaging station
- Aquifer boundary (approximate)
- —1610— Groundwater contour line with elevation dashed where inferred.
- Seismic survey line—Newcomb 1953

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

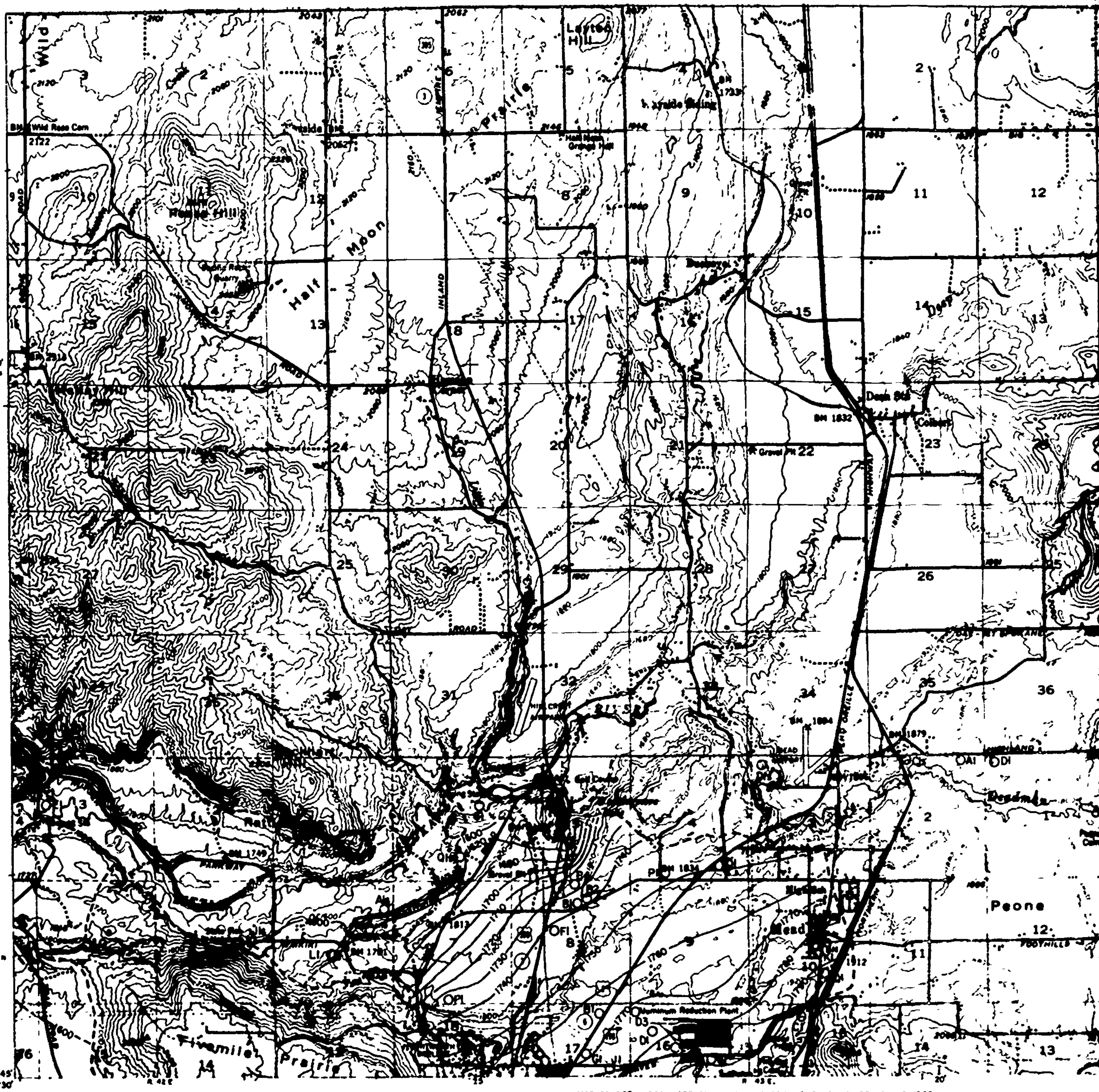
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 16

DACW67-73-C-0096

"PLATE 303-28"



MAP SOURCE: USGS DEER PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

1 MILE

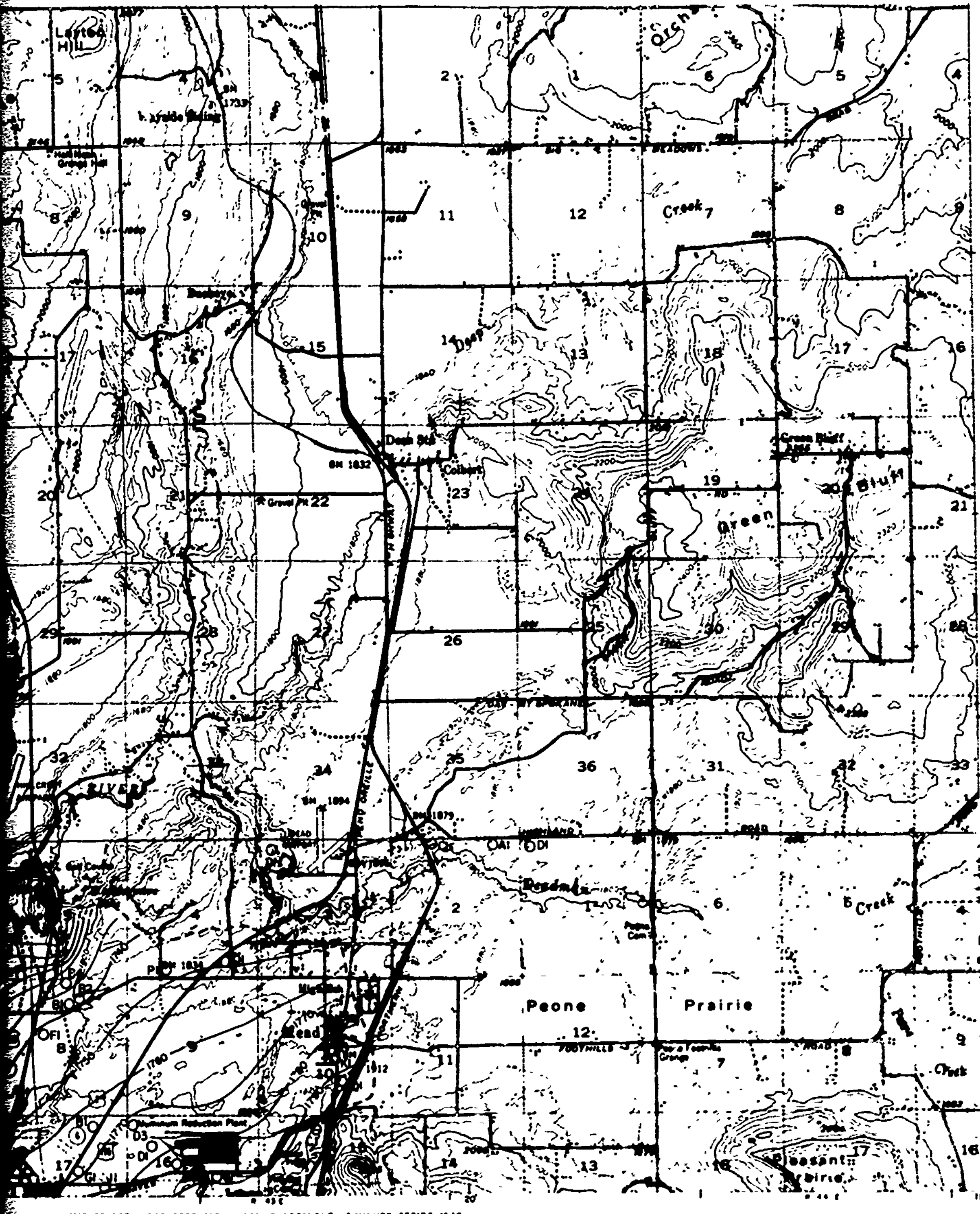
7000 FEET

GRAPHIC SCALES

LEGEND

- ○ Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- ● Gaging station
- Aquifer boundary (approximate)
- --1610-- Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line – Newcomb 1953

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



MAP SOURCE: USGS DEER PARK, WASH QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line – Newcomb 1953

KENNEDY TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

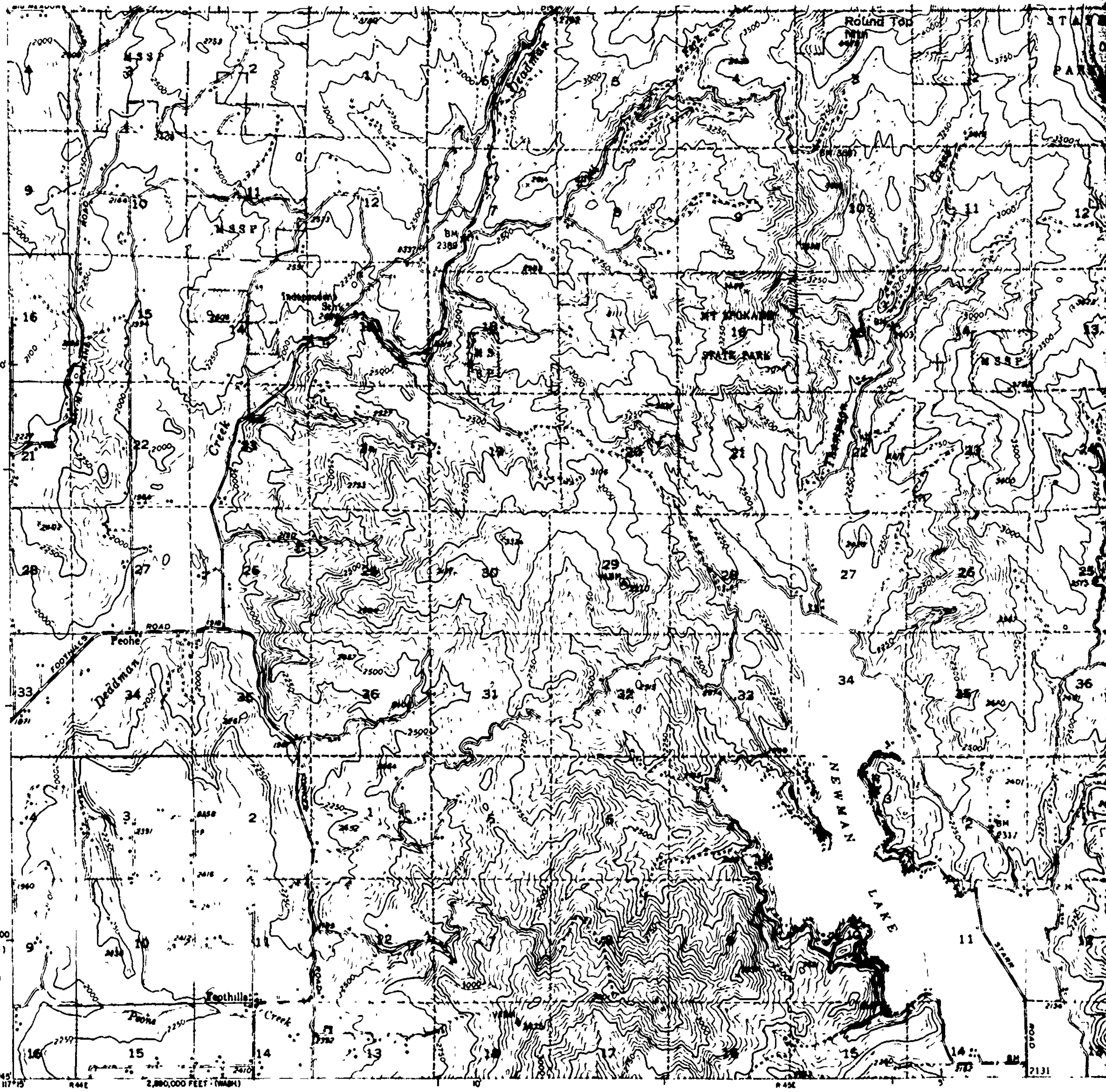
U.S. ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 17

DACW67-73-C-0090

PLATE 303-29



MAP SOURCE USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1960

1/2 0 1 MILE

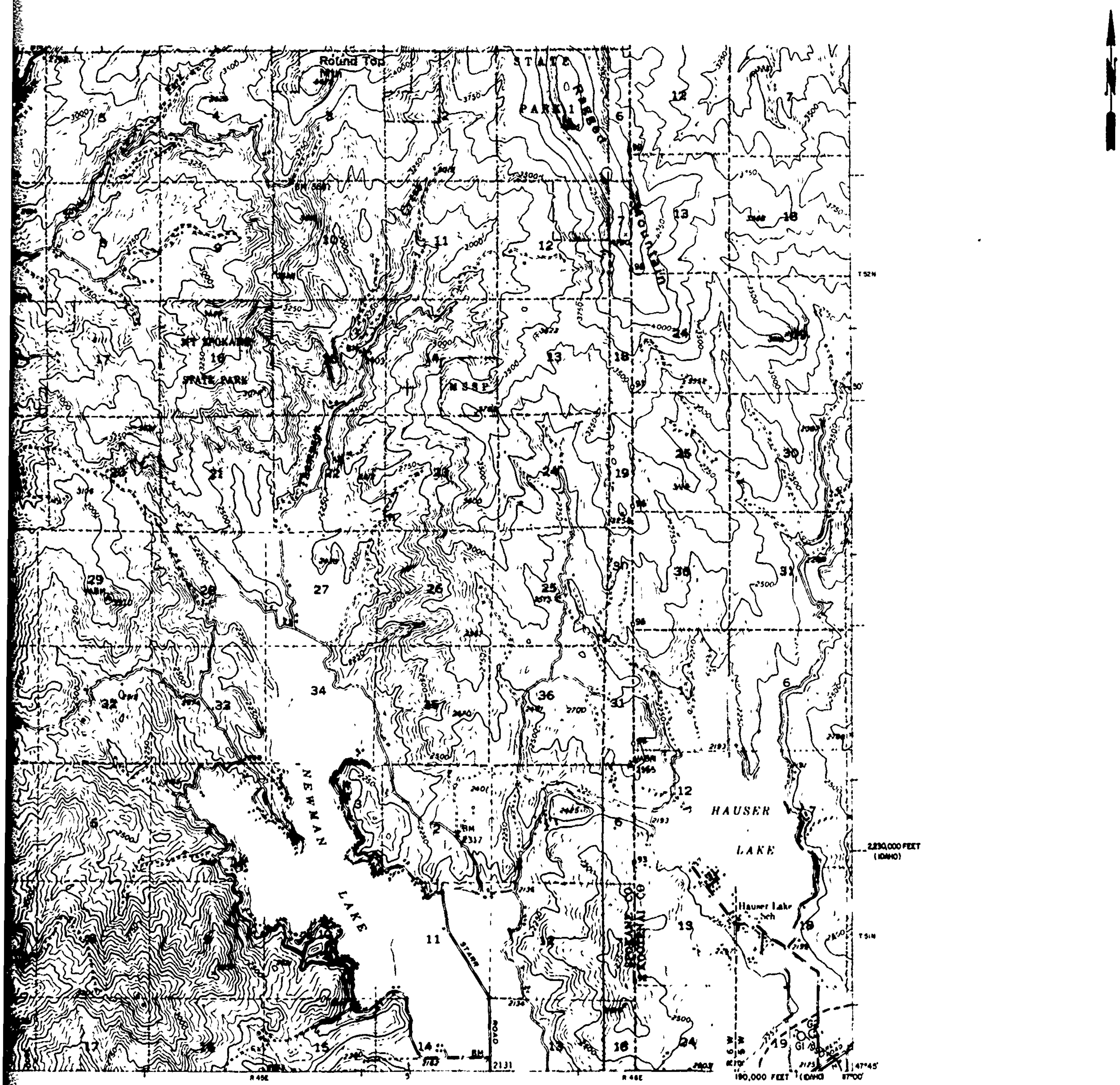
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

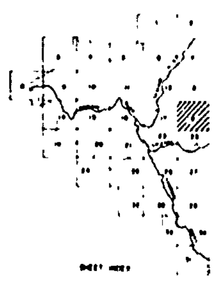
LEGEND

- ○ Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifier boundary (approximate)
- — 1610 — Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line — Newcomb 1953

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY



MAP SOURCE: USGS MT SPOKANE, WASH-IDAHO, QUADRANGLE, 15 MINUTE SERIES, 1960



LEGEND

- ○ Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifier boundary (approximate)
- —1610-- Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line – Newcomb 1953

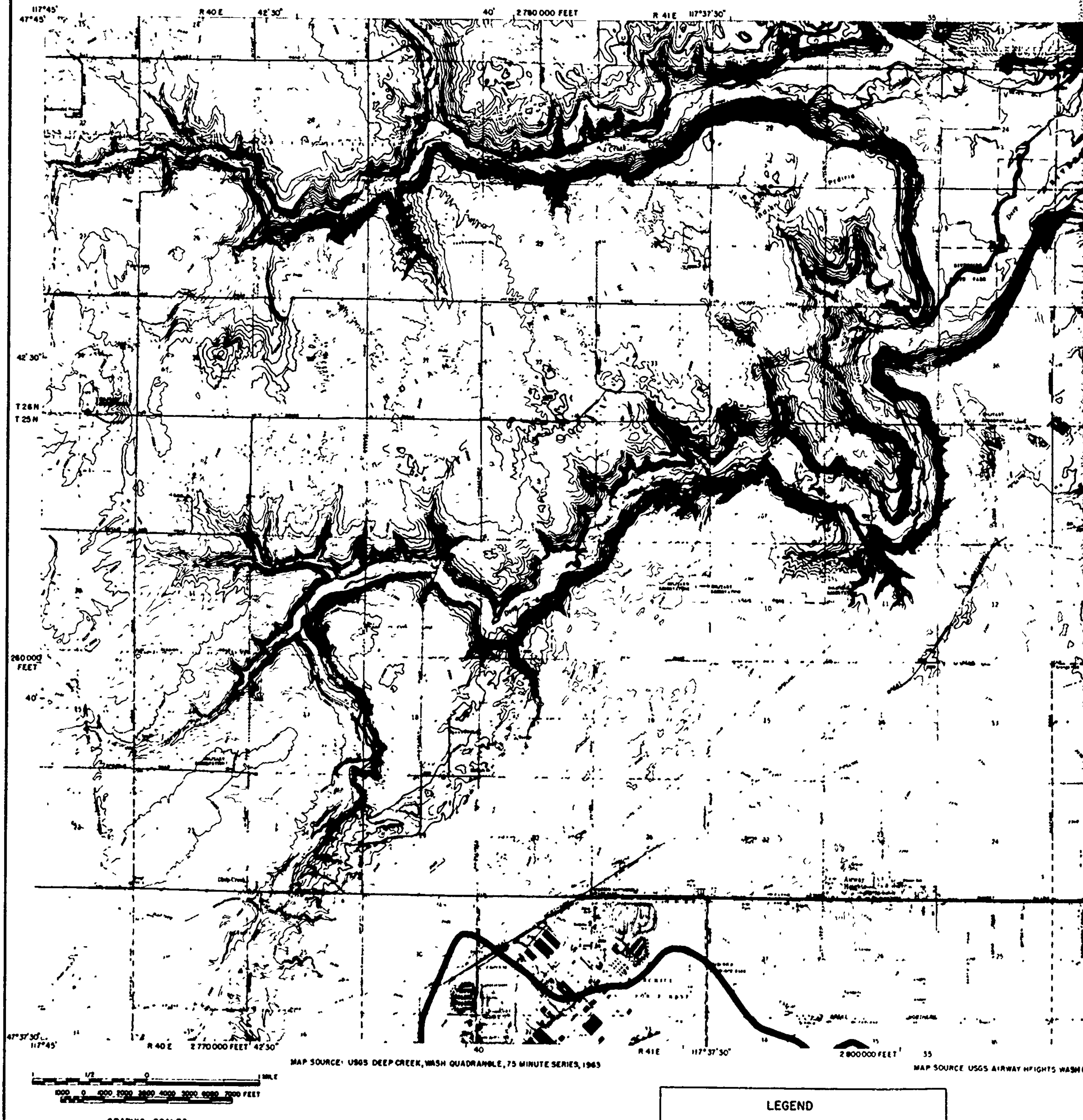
KENNEDY - TUDOR CONSULTING ENGINEERS SEATTLE WASHINGTON	U S ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 18

DACW67-73-C-0096

"PLATE 303-30"



MAP SOURCE: USGS DEEP CREEK, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS AIRWAY HEIGHTS WASH

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

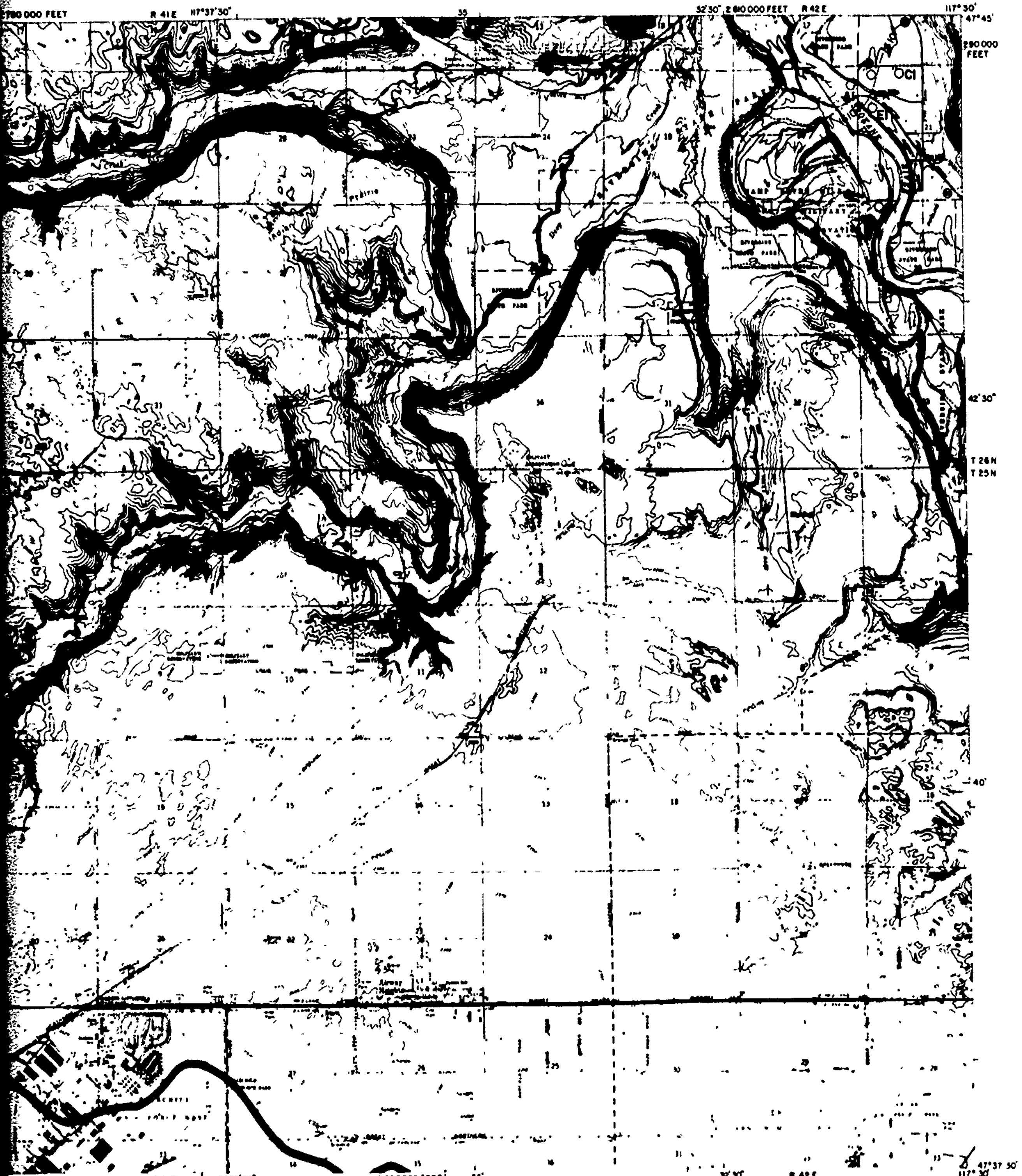
GRAPHIC SCALES

REVISIONS

SYMBOL	DESCRIPTION	DATE	BY

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifier boundary (approximate)
- —1610— Groundwater contour line with elevation Dashed where inferred.
- Seismic survey line - Newcomb 1953

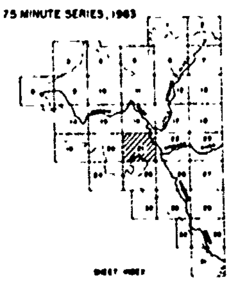


5 MINUTE SERIES, 1963

MAP SOURCE USGS AIRWAY HEIGHTS WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifier boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line - Newcomb 1953



KENNEDY - TUDOR CONSULTING ENGINEERS SEATTLE, WASHINGTON

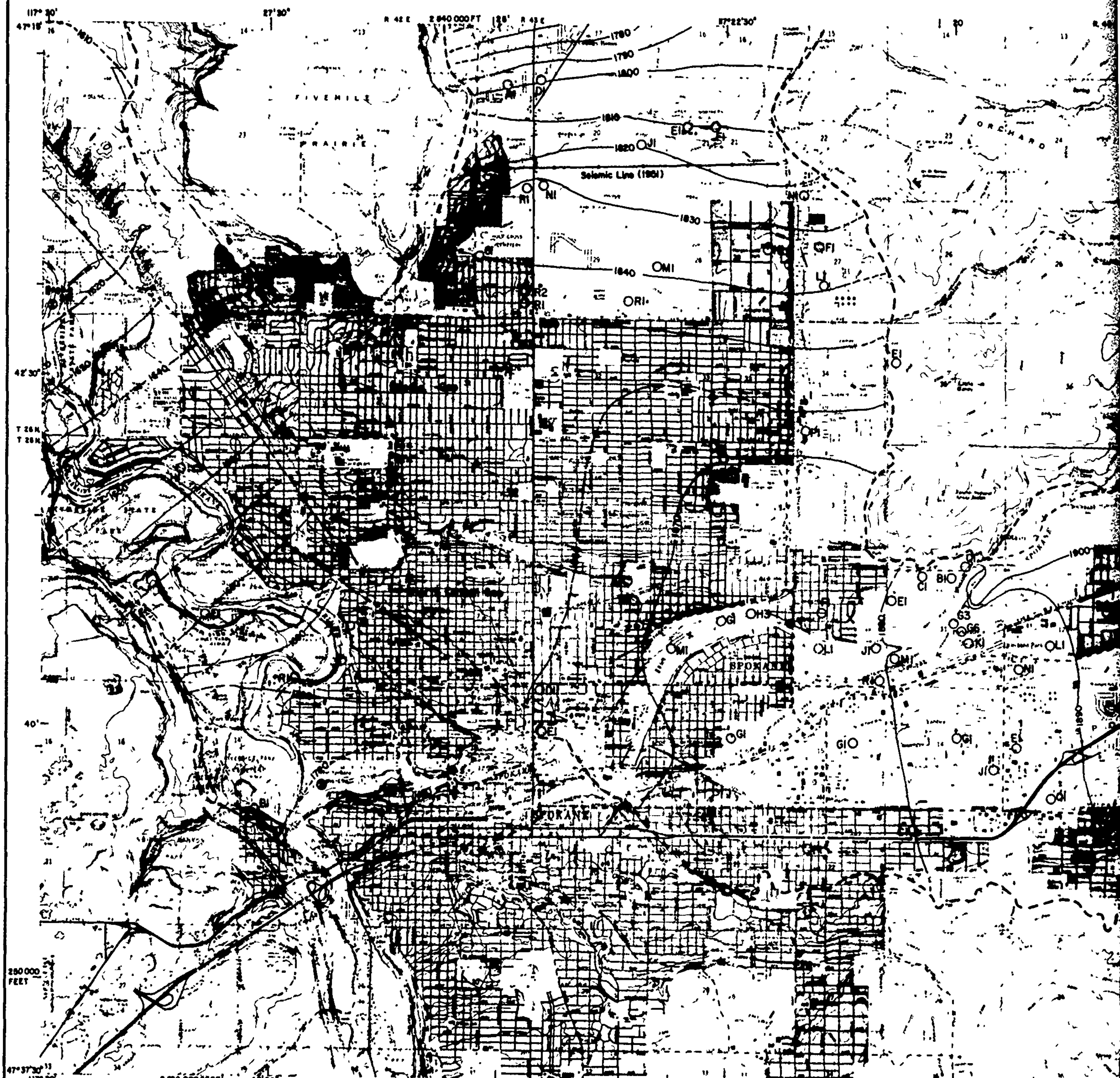
U S ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 21

DACW67-73-C-0096

PLATE 303-31



MAP SOURCE: USGS SPOKANE NW., WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

MAP SOURCE USGS SPOKANE NE, WASH

1/2 0 1 MILE

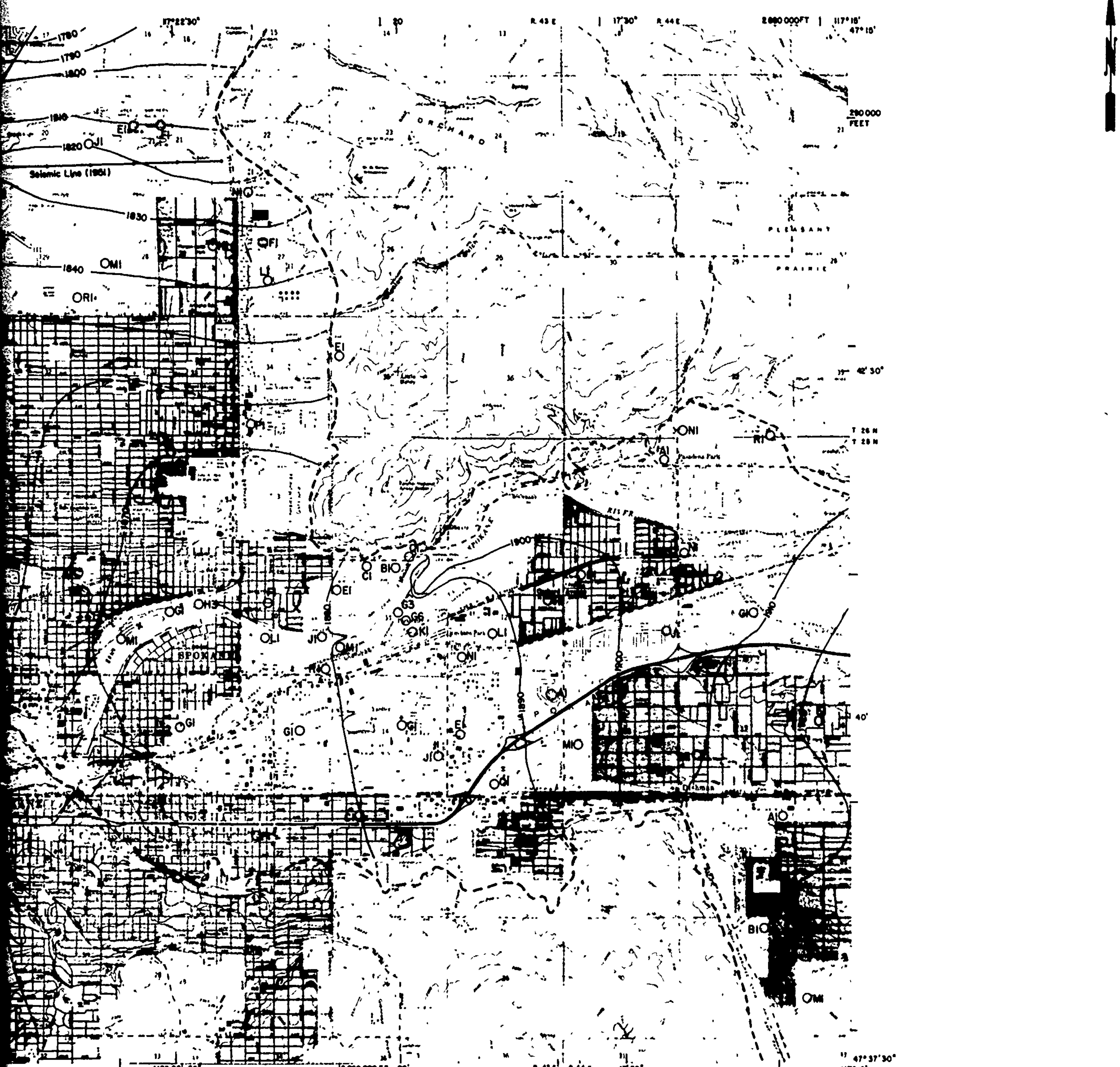
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred
- Seismic survey line – Newcomb 1953



...ERIES, 1963

MAP SOURCE: USGS SPOKANE N.E., WASH. QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 — Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line — Newcomb 1953

KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE WASHINGTON

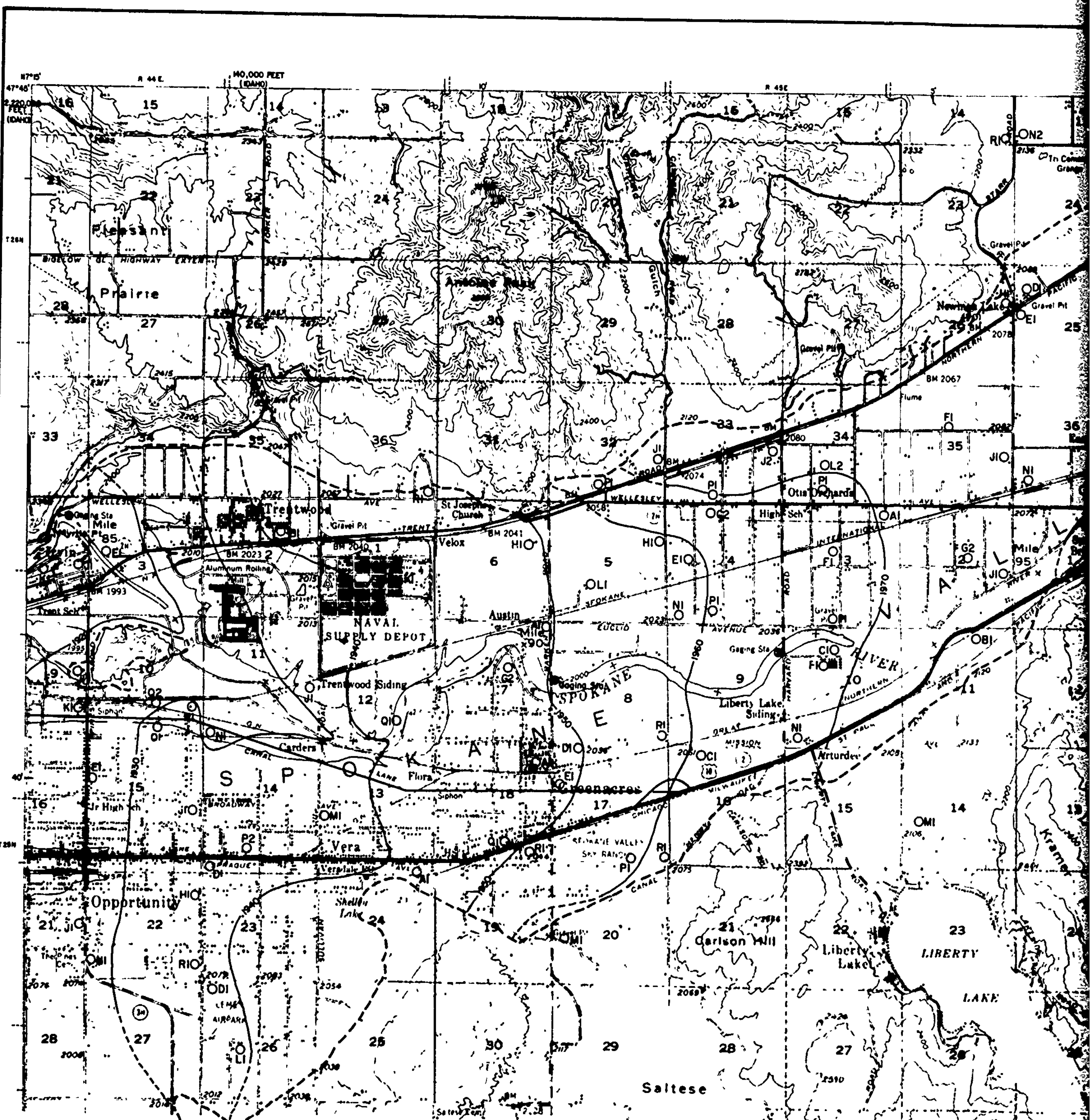
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 22

DACW67-73-C-0000

PLATE 303-32



GRAPHIC SCALES

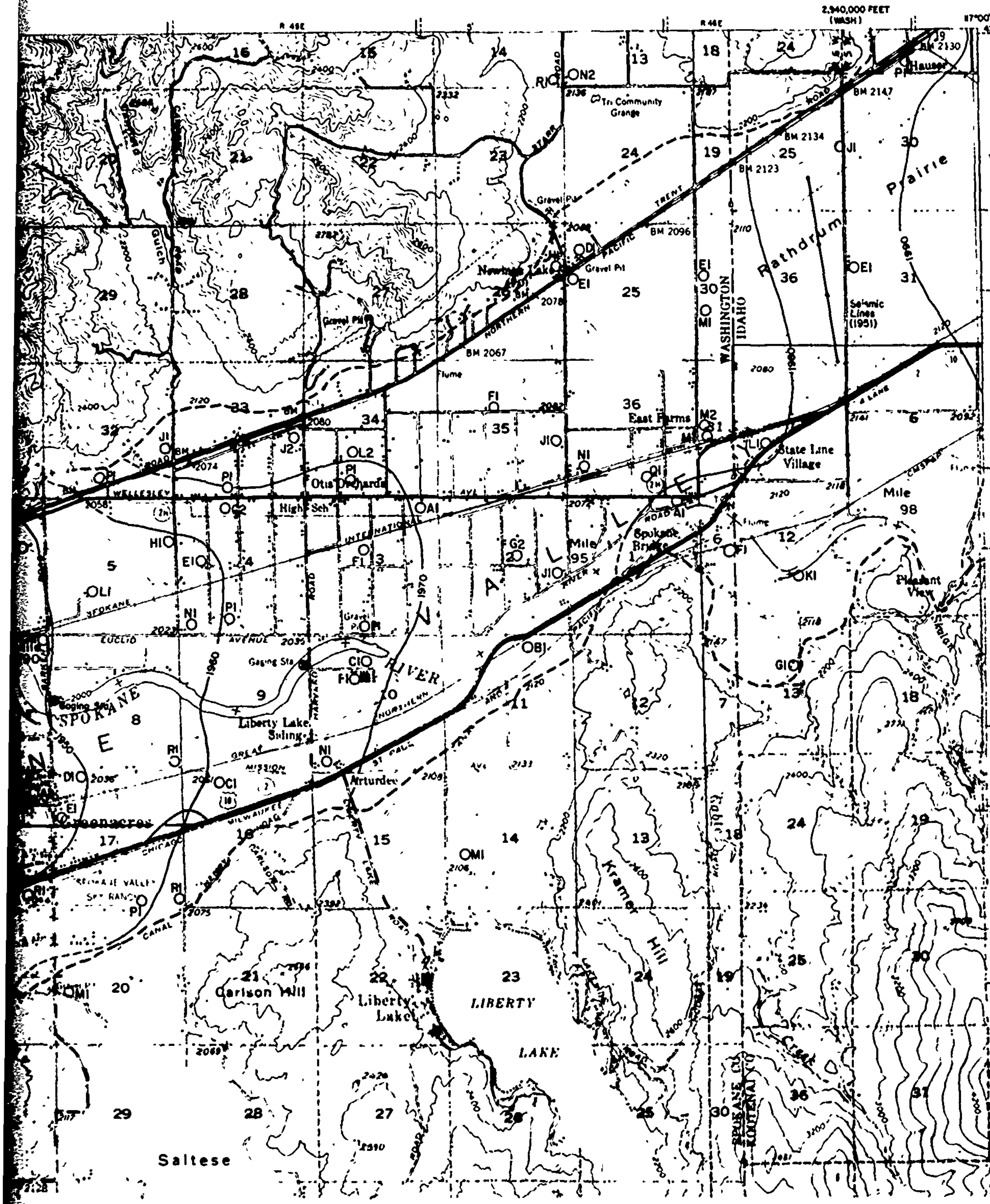
MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line - Newcomb 1953

REVISIONS

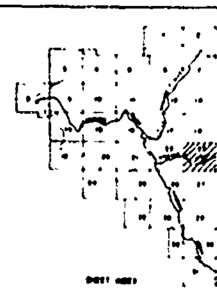
SYMBOL	DESCRIPTION	DATE	BY



MAP SOURCE USGS GREENACRES, WASH-IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line - Newcomb 1953



KENNEDY - TUDOR CONSULTING ENGINEERS SEATTLE, WASHINGTON

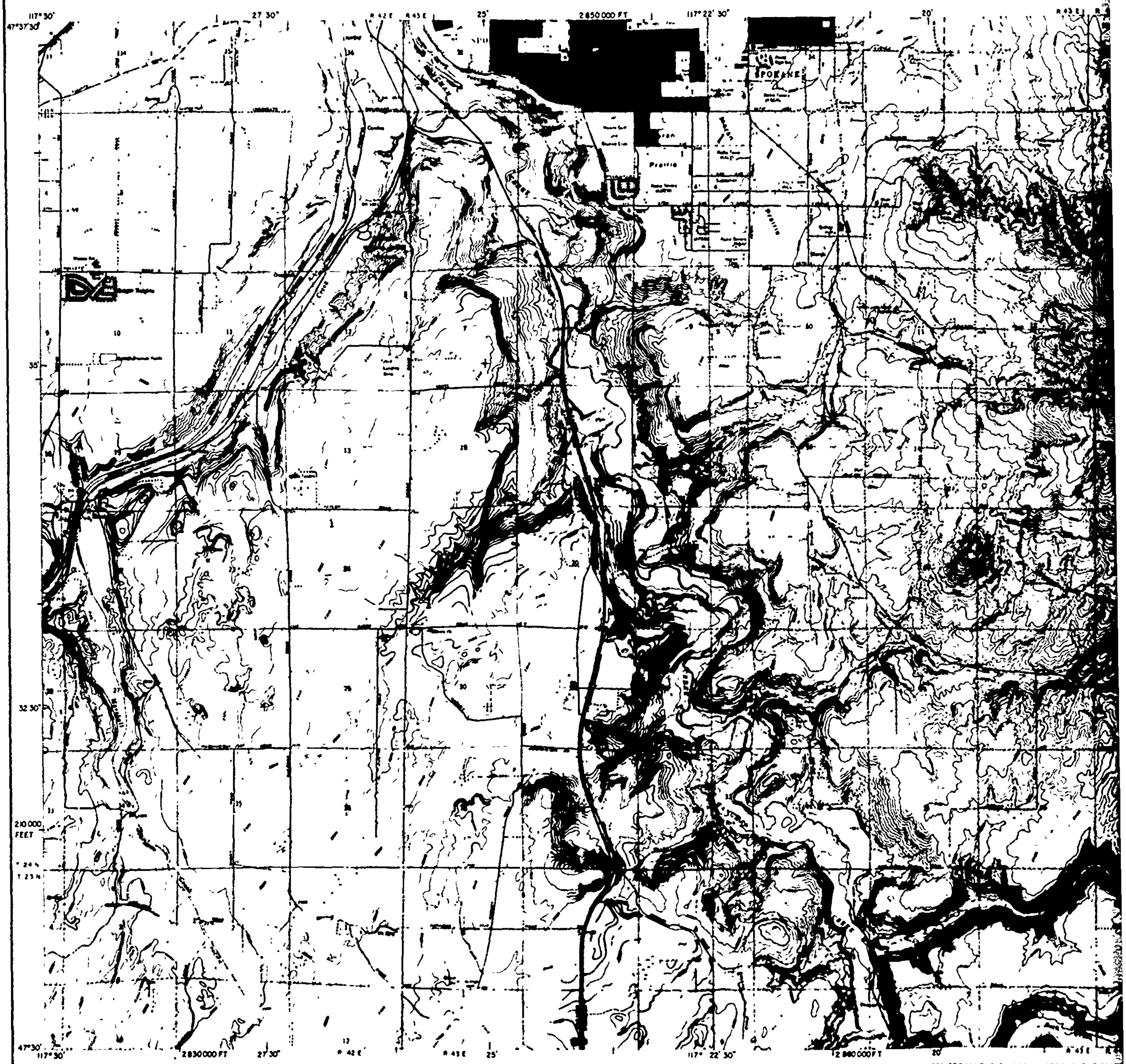
U S ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 23

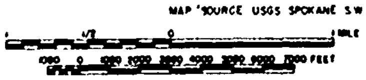
DACW 67-73-C-0096

PLATE 303-33



MAP SOURCE USGS SPOKANE S.W., WASH QUADRANGLE, 7.5 MINUTE SERIES 1963

MAP SOURCE USGS SPOKANE S.E., WASH QUADRANGLE, 7.5 MINUTE SERIES

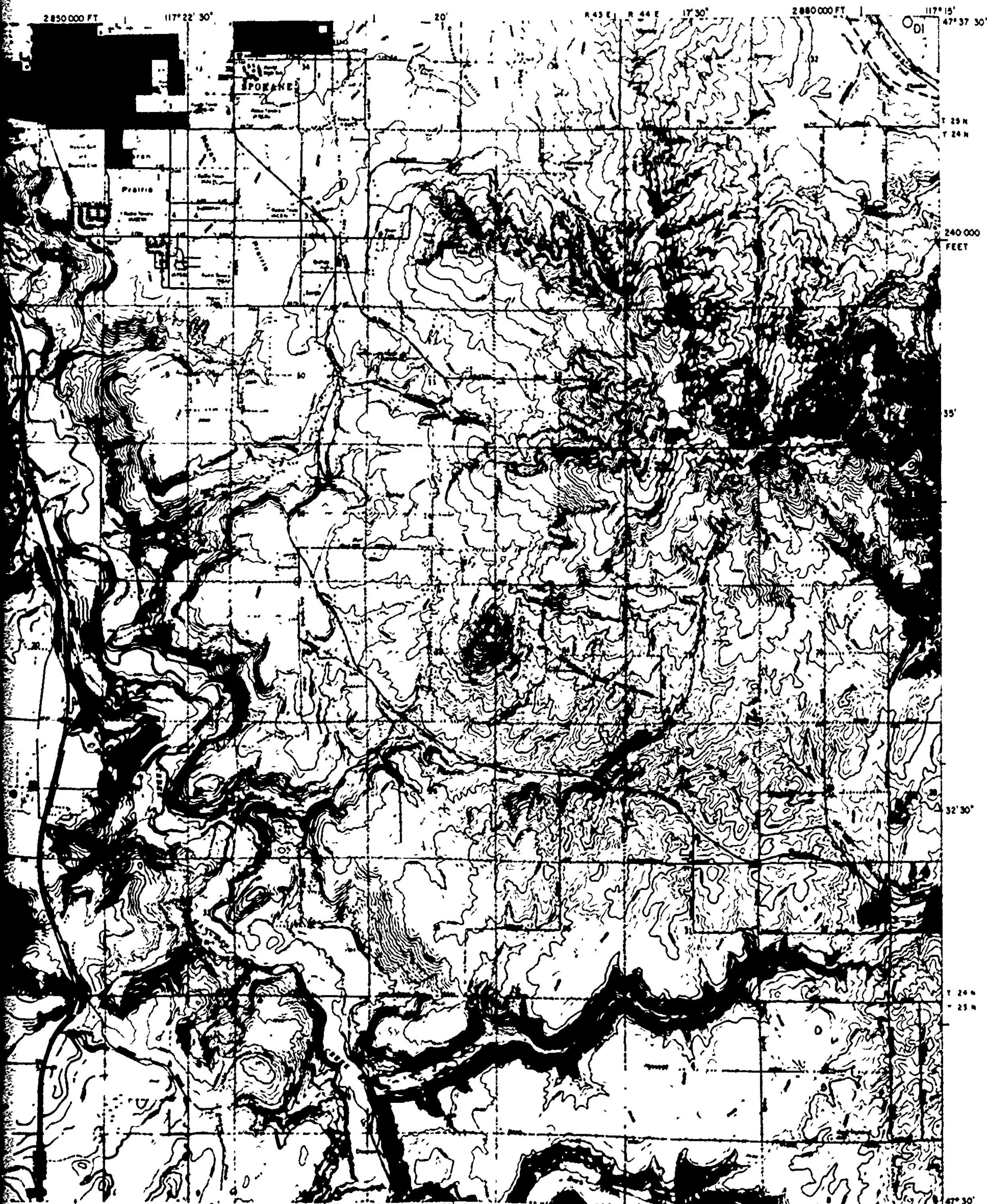


GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

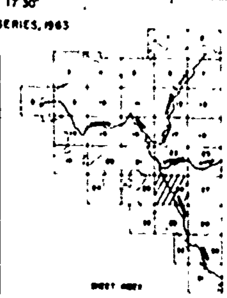
- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 — Groundwater contour line with elevation. Dashed where inferred.
- Seismic survey line – Newcomb 1953



MAP SOURCE USGS SPOKANE S E, WASH QUADRANGLE, 7.5 MINUTE SERIES, 1963

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifier boundary (approximate)
- —1610— Groundwater contour line with elevation. Dashed where inferred
- Seismic survey line – Newcomb 1953



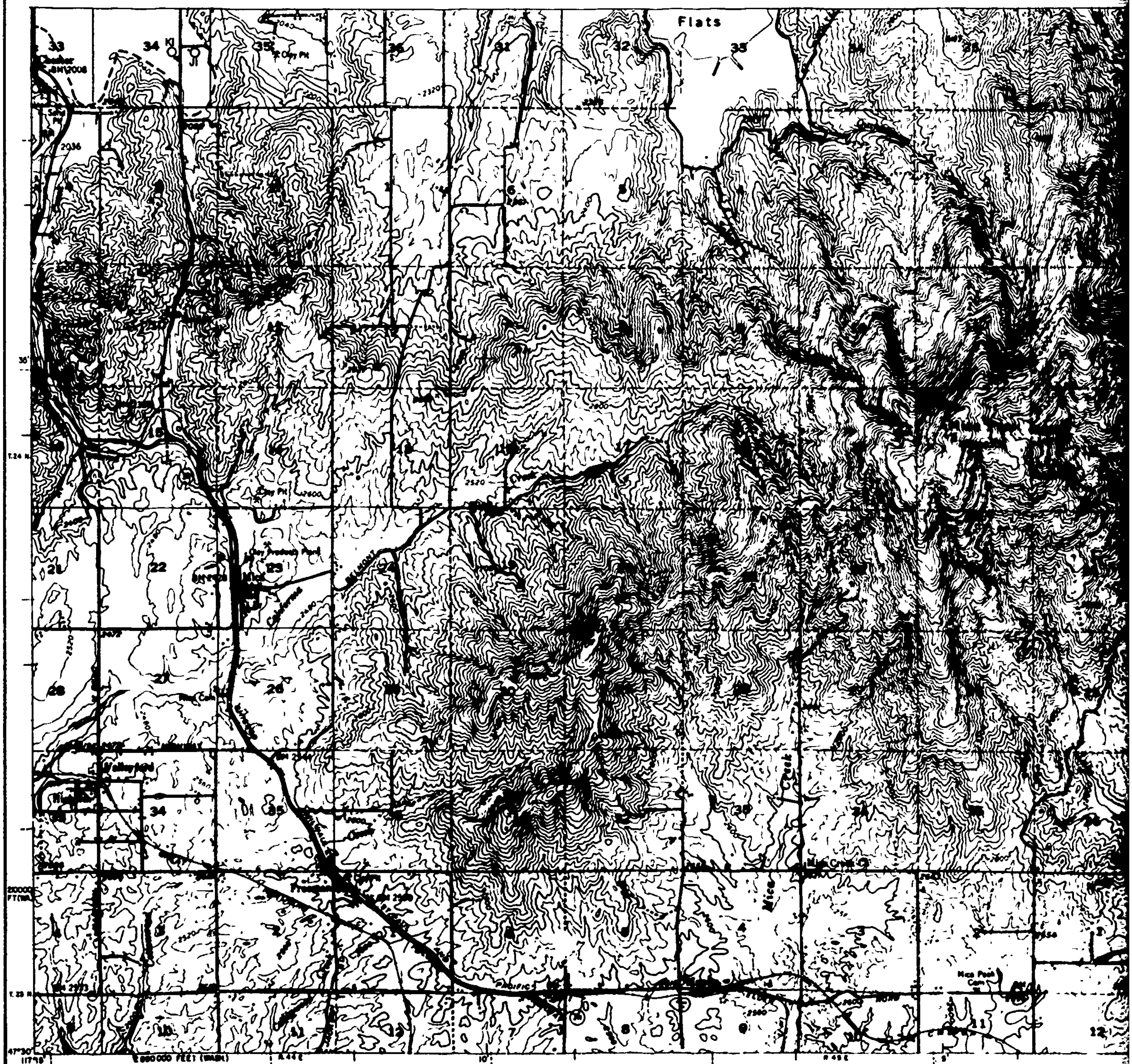
KENNEDY - TUDOR
CONSULTING ENGINEERS
SEATTLE, WASHINGTON

U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 26

PLATE
303-34



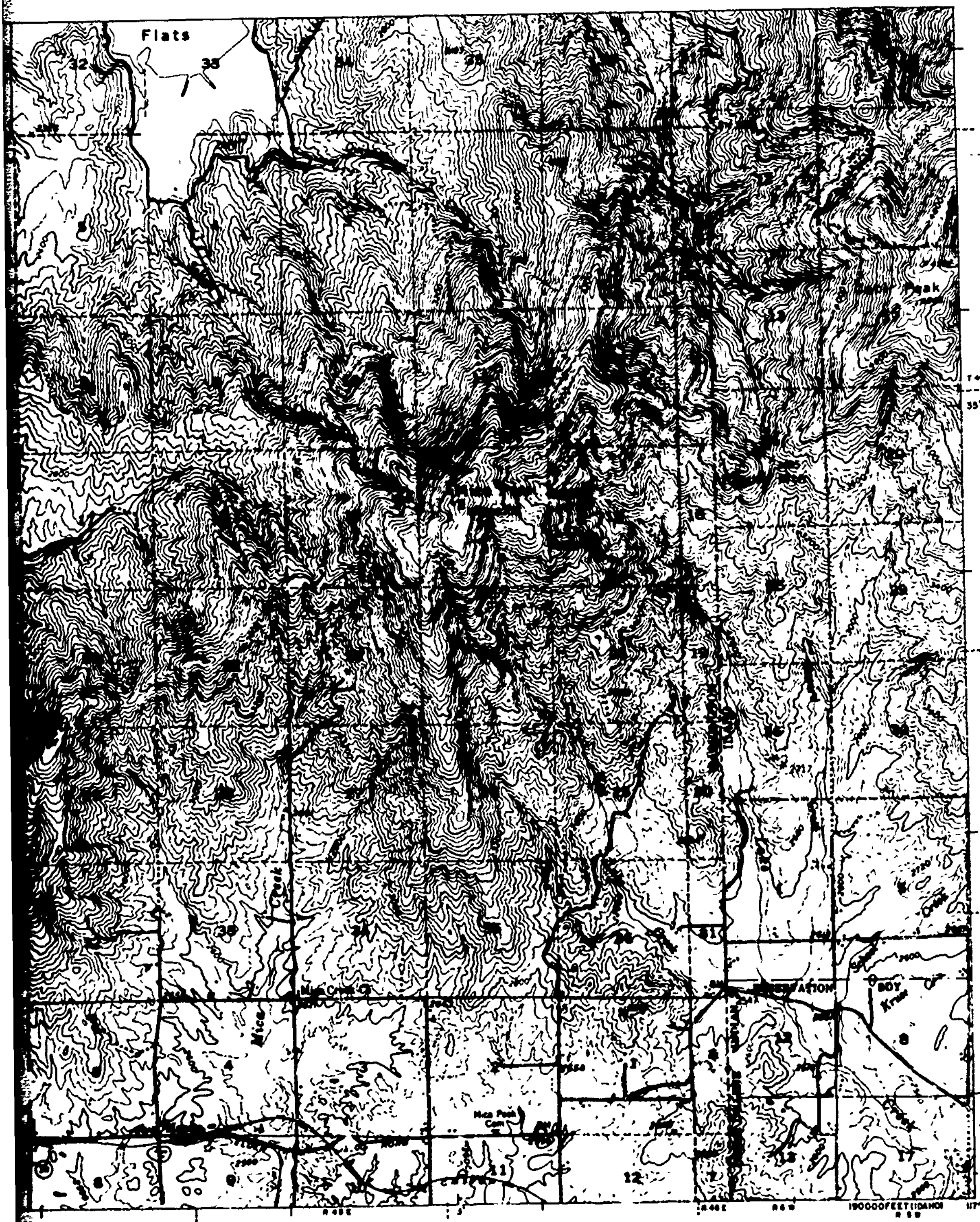
MAP SOURCE: USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949

GRAPHIC SCALES

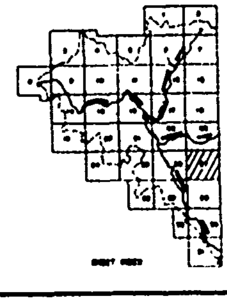
REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred, question mark where unknown.
- Seismic survey line Newcomb 1953



MAP SOURCE: USGS GREENACRES, WASH - IDAHO QUADRANGLE, 15 MINUTE SERIES, 1949



LEGEND

- Well (See listing in Table B-1, Appendix B)
- Spring (See listing in Table B-2, Appendix B)
- Gaging station
- Aquifer boundary (approximate)
- 1610 Groundwater contour line with elevation. Dashed where inferred, question mark where unknown.
- Seismic survey line - Newcomb 1953

U S ARMY

CORPS OF ENGINEERS

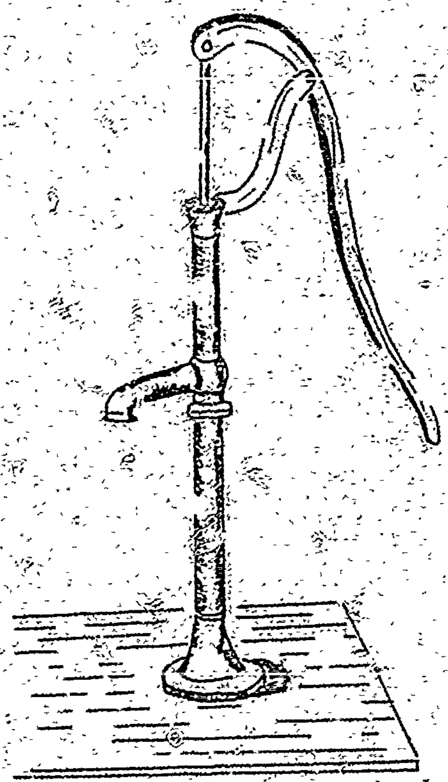
SEATTLE, WASHINGTON

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

GROUNDWATER AREA 27

PLATE 303-35



SECTION 405

GROUNDWATER QUALITY DATA

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 405

GROUNDWATER QUALITY DATA

15 November 1974

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

INDEX

Subject		Page
Introduction		405 - 1
Available Prior Existing Data		
General		405 - 1
Primary Aquifer		405 - 2
Basalt Aquifer		405 - 3
Other Aquifers		405 - 3
Summary Comparison of All Aquifers		405 - 4
Identification of Data Gaps and Selection of Supplemental Sampling Programs		
Primary Aquifer		405 - 4
Basalt Aquifer		405 - 6
Other Aquifers		405 - 6
Sampling Program and Results		405 - 6
Summary Groundwater Quality		405 - 7
Table and Plate Indices		405 - b
Appendix I	Water Quality Data Primary Aquifer	405 - [illegible]
Appendix II	Water Quality Data Basalt Aquifer	405 - 63
Appendix III	Water Quality Data Little Spokane Valley	405 - 83
Appendix IV	Water Quality Data Other Aquifers	405 - 87

TABLE INDEX

Table No.	Subject	Page
1	Summary of Available Groundwater Quality Data, Primary Aquifer	405 - 8
2	Summary of Available Groundwater Quality Data, Basalt Aquifer	405 - 9
3	Summary of Available Groundwater Quality Data, Little Spokane Basin and Other Aquifers	405 - 10
4	Summary of Avilable Groundwater Quality for All Aquifers	405 - 11
5	Supplemental Groundwater Sampling Program	405 - 12
6	Results of Groundwater Sampling Program	405 - 13
7	Summary of Groundwater Quality in the Study Area	405 - 14

PLATE* INDEX

Plate No.	
405-1	Groundwater Quality Locations Primary Aquifer
405-2	Groundwater Quality Locations Basalt and Other Aquifers

* All plates are large drawings bound at the end of this section.

SECTION 405

GROUNDWATER QUALITY DATA

Introduction

This section has four objectives:

(1) To summarize prior existing groundwater quality data

(2) Identify data gaps in the prior existing record

(3) Describe the selection of a supplemental sampling program to fill data gaps

(4) Report the results of the supplemental sampling program.

Interpretation of the groundwater quality data is not an objective of this section. Interpretation and analysis are covered in Section 608.2.

There are two groundwater regimes of major areal extent, the primary Spokane Valley aquifer and the basalt aquifer, plus a number of other aquifers of smaller extent. The four objectives listed above are addressed in terms of data divided into aquifer categories designated "primary", "basalt" and "other".

An incidental objective of this section is the development of a groundwater quality file for insertion in the simulation model. The groundwater of the primary aquifer, most of which does not originate in the study area, forms an important constituent of the basin surface waters which must be accounted for in simulation of surface water quality.

Available Prior Existing Data

General. The general availability of groundwater quality data is

developed in Section 307-9. It is shown in 307-9 that there is a large amount of general chemical quality data available in the raw data files of the Department of Social and Health Services (DSHS) which are not categorized or systemitized except by County and which are not in STORET. These DSHS files are explored as part of this section to fill specific data gaps prior to development of the supplemental sampling program. Their usefullness is greatest in the areas of the basalt and other aquifers which are not as well represented in STORET and were not included in the USGS-EPA special program.

Primary Aquifer. Due to the great interest in this aquifer which provides, with one exception*, the entire municipal, industrial and agricultural supply of the Urban Planning Area, it is possible to assemble for this aquifer water quality data from thirty wells, all based on samples in the period 1970-74 and all covering a significant range of quality parameters. These data are all available from either STORET or the recent USGS-EPA program. These thirty wells and their quality data are shown in Appendix I. An overall evaluation of typical primary aquifer quality is presented in Table 1 based on statistical summary of twenty-five of the thirty wells. The following five wells are omitted from the summary because they are untypical in some respect as indicated below:

Number	Name	Anomalous Data
25/42-13B1	Spokane Cold Storage	High manganese
25/43-24G1	East Spokane #1	High solids
25/44-2Q1	Kaiser Eastgate	High solids, chlorides, chrome, zinc
26/45-36N1	G. N. Siverson	High iron and zinc
26/45-36Q1	Borden	High zinc

* The one exception is the Kaiser Trentwood industrial cooling water diversion from the Spokane River.

It is evident that these five wells are being affected by influences not common to the rest of the primary aquifer wells and are not representative of typical conditions.

The locations of the wells listed in Appendix I are shown on Plate 608-1.

Basalt Aquifer. Groundwater quality data are available for 46 wells in the Basalt Aquifer by extending the search to the DSHS source and utilizing data back to 1942. The data are listed in Appendix II. Sources utilized are as follows:

Source	Number of Wells
DSHS	31
Van Denburgh and Santos	13
USGS (Unpublished)	1
Weigle and Mundorf	1
	46

Locations of the wells listed in Appendix II are shown in Plate 608-2. A summary of quality data for the Basalt Aquifer based on statistical analysis of the data in Appendix II is presented in Table 2.

Other Aquifers. Of the other aquifers, the alluvium of the Little Spokane River valley is the most important from both an areal and utilization standpoint. Therefore, this area is treated separately and the data for the remaining areas is lumped together. Data for 16 wells in the Little Spokane basin and for 19 wells in other locations are available entirely from DSHS records for the period 1970-73. These data are compiled in Appendices III and IV respectively and locations are shown on Plate 608-2. Summarized data are shown in Table 3.

Summary Comparison of All Aquifers. Mean values of quality parameters for all aquifers are summarized in Table 4.

Identification of Data Gaps and Selection of Supplemental Sampling Program

Primary Aquifer. The data shown in Table 1, Appendix I and Plate 608-1 when evaluated for parameter and areal coverage indicates no need for expansion of the parameter list beyond the USGS-EPA selection but does indicate the need for areas not previously sampled.

Fifteen general areas of the primary aquifer are found to be inadequately represented. Selected wells to represent twelve of the fourteen areas are shown on Plate 608-1. There are no available wells in or even sufficiently near to areas marked 2, 8 and 9 on Plate 608-1 to fulfill requirements. There appears to be no present groundwater development at these sites, which therefore must remain gaps.

In addition to the wells selected for additional area coverage, two wells previously sampled by USGS-EPA are selected for an additional sampling to confirm what appear to be changing conditions revealed by the four periodic samples under USGS-EPA. The two wells selected for repeat sampling are as follows with the apparent anomalies in data which caused them to be selected:

Number	Name	Anomalous Data
25/42-13B1	Spokane Cold Storage	Solids moved steadily up from 179 to 231 mg/l and manganese jumped from nil to 140 ug/l
25/44-2Q1	Kaiser East Gate	Large increase in solids from 175 to 329, jump in chlorides from less than 10 mg/l to 60 mg/l and chromium from nil to 30 ug/l

The well at Kaiser Mead, number 26/43-16F, although previously sampled, but not in the USGS-EPA full spectrum of parameters, is selected for additional analysis to fill out the data on the downstream end of the aquifer.

Table 5 lists the wells selected for sampling and analysis in the primary aquifer. Those for additional areal coverage inside the study area are P-1, 3, 4, 5, 6, 7, 10, 11, 12, 13 and 14. One of the newly completed wells by the Bureau of Reclamation east of the Idaho border and outside the study area is selected for the opportunity it affords of getting a sample representative of the water entering from Idaho. This well is designated P-W, 5/51-28N. Wells designated sample P-X and P-Y are the repeat samples of USGS-EPA points, Kaiser Eastgate and Spokane Cold Storage respectively. Sample P-Z is the expanded parameter sample of Kaiser Mead.

The analysis program shown for all wells in the primary aquifer typically includes all the USGS-EPA chemical parameters. Bacteriological and hexane extractables are added for those in and downstream of

development. Aluminum is added for those near the aluminum industries.

Basalt Aquifer. Both areal and parameter coverage available are adequate for an overview of Basalt Aquifer water quality except that there are no checks available on possible contamination at three communities. Sampling and analysis for wells near Airways Heights, Spangle, and Latah are selected as shown on Table 5. Since the interest in this coverage is primarily possible pollution from the adjoining development, the analysis selected is bacteriological and detergents. Basalt aquifer samples are identified by the letter B.

Other Aquifers. The data gap situation for other aquifers is similar to that stated above for the basalt. Data are adequate in general but there are three areas of development for which there is no check on potential pollution. Three locations as indicated in Table 5 are sampled and analyzed for bacterial indicators and detergent. Samples in other aquifers are identified by the letter O.

Sampling Program and Results. Samples were collected in the period June 4, 1974 to June 10, 1974. Analyses were performed in accordance with the schedule shown on Table 5 by Pacific Environmental Laboratory of San Francisco. All analyses are according to "Standard Method for the Examination of Water and Wastewater", Current Edition, APHA, except as noted below. Fluoride was analyzed by specific ion eletrode. Mercury was analyzed by flameless atomic absorption spectrophotometry. Cadmium, chromium, copper, iron, lead, manganese, potassium, sodium, and zinc were

analyzed by atomic absorption spectrophotometry. The conductivity, pH, and water temperature were analyzed in the field. Coliform tests were performed in the field laboratory by the membrane filter method.

It should be noted that the Kjeldhal nitrogen determination reported here are by the manual micro Kjeldhal apparatus in accordance with standard methods and are not of the same degree of sensitivity as those reported by USGS-EPA which are done by an automated apparatus. In both cases the amounts reported are at the minimum range of the respective methods.

Reports of the analyses are summarized in Table 6.

Summary Groundwater Quality

The water quality data gained in the supplementary sampling and analysis program reported above are combined with the prior existing data to arrive at mean values representative of each aquifer. These results are shown in Table 7 .

TABLE 1

SUMMARY OF PRIOR AVAILABLE GROUNDWATER QUALITY DATA FOR THE PRIMARY AQUIFER

Parameter	Units	Average Value	Standard Deviation	# Samples
Conductivity at 25°C	umhos	285	56	201
Residue (Total)	mg/l	177	46	150
Residue (Diss-180°)	mg/l	171	26	49
Residue	TON/AFT	0.23	0.04	48
pH	-	7.7	0.6	198
Temp.	°C	10.7	1.8	69
D. O.	mg/l	8.3	1.4	5
Hardness (As $CaCO_3$)	mg/l	157	40	202
NH_3 -N	mg/l	0.015	0.008	49
NO_2-N	mg/l	0.002	0.002	49
NO_3-N	mg/l	1.521	1.258	50
Kjel-Nitrogen (N)	mg/l	0.111	0.146	49
PO_4-P (Total)	mg/l	0.014	0.012	50
PO_4-P(Ortho)	mg/l	0.010	0.012	49
Cl	mg/l	4.7	3.6	198
As (Diss)	ug/l	5	10	49
Cd (Diss)	ug/l	0	0	49
Cr (Diss)	ug/l	0	0	49
Cu (Diss)	ug/l	6	11	49
Fe (Diss)	ug/l	28	32	49
Fe (Total)	ug/l	169	356	146
Pb (Diss)	ug/l	2	3	43
Pb (Total)	ug/l	19	8	20
Mn	ug/l	7	10	201
Hg (Total)	ug/l	2	4	61
Zn (Diss)	ug/l	26	32	50
MBAS	mg/l	0.02	0.03	45

TABLE 2

SUMMARY OF AVAILABLE GROUNDWATER
QUALITY FOR THE BASALT AQUIFER

Parameter	Units	Average Value	Standard Deviation	# Samples
Conductivity at 25°	umhos	263	90	95
Dissolved Solids				
Calculated *	mg/1	181	33	52
Residue (180°C)	mg/1	177	34	64
pH	-	7.7	0.3	95
Temp.	°C	14.0	3.3	56
Color	Color Units	5	7	90
Hardness, as $CaCO_3$	mg/1	108	38	97
ALK. as $CaCO_3$	mg/1	120	46	31
NO_3-N	mg/1	1.686	2.884	96
Total PO_4-P	mg/1	0.088	0.121	31
Ortho PO_4-P	mg/1	0.070	0.099	2
Cl	mg/1	5.1	7.0	96
SO_4	mg/1	14.5	11.2	96
F	mg/1	0.308	0.215	96
Fe	ug/1	140	178	88

* Based on the sum of the concentrations of the individual major constituents.

TABLE 3

SUMMARY OF PRIOR AVAILABLE GROUNDWATER QUALITY DATA FOR THE LITTLE SPOKANE BASIN AND OTHER AQUIFERS

		Little Spokane Basin Aquifer			Other Aquifers		
Parameter	Units	Average Value	Standard Deviation	No. of Samples	Average Value	Standard Deviation	No. of Samples
pH	-	7.7	0.4	16	7.4	0.4	19
Conductivity	umhos/cm	292	106	16	285	145	19
Color	Color Units	4	2	16	7	6	19
Hardness ($CaCO_3$)	mg/l	151	64	16	136	72	19
Alkalinity ($CaCO_3$)	mg/l	139	54	16	114	58	19
Fe	ug/l	100	100	16	161	167	19
SO_4	mg/l	17.7	9.4	16	16.7	9.6	19
Cl	mg/l	3.4	4.5	16	8.6	10.3	19
F	mg/l	0.166	0.093	16	0.247	0.301	19
NO_3-N	mg/l	1.418	1.624	16	1.046	1.504	19
PO_4-P	mg/l	0.095	0.082	16	0.115	0.272	19

TABLE 4

SUMMARY OF AVAILABLE GROUNDWATER
QUALITY FOR ALL AQUIFERS

Parameter	Units	Mean Values by Aquifer			
		Primary	Basalt	Little Spokane	Other
Conductivity	umhos/CM	285	263	292	285
Residue (Total)	mg/l	177	-	-	-
Residue (180°C-Diss)	mg/l	171	177	-	-
Residue	TON/AFT	0.23	-	-	-
pH	-	7.7	7.7	7.7	7.4
Temp.	°C	10.7	14.0	-	-
D. O.	mg/l	8.3	-	-	-
Color	Color Units	-	5	4	7
Hardness ($CaCO_3$)	mg/l	157	108	151	136
ALK ($CaCO_3$)	mg/l	-	120	139	114
NH_3-N	mg/l	0.015	-	-	-
NO_2-N	mg/l	0.002	-	-	-
NO_3-N	mg/l	1.521	1.686	1.418	1.046
Kjel-Nitrogen (N)	mg/l	0.111	-	-	-
PO_4-P (Total)	mg/l	0.014	0.088	0.095	0.115
PO_4-P (Ortho)	mg/l	0.010	0.070	-	-
Cl	mg/l	4.7	5.1	3.4	8.6
SO_4	mg/l	-	14.5	17.7	16.7
F	mg/l	-	0.308	0.166	0.247
AS (Diss)	ug/l	5	-	-	-
Cd (Diss)	ug/l	0	-	-	-
Cr (Diss)	ug/l	0	-	-	-
Cu (Diss)	ug/l	6	-	-	-
Fe (Diss)	ug/l	28			
Fe (Total	ug/l	169	140 *	100 *	161 *
Pb (Diss)	ug/l	2	-	-	-
Pb (Total)	ug/l	19	-	-	-
Mn	ug/l	7	-	-	-
Hg (Total)	ug/l	2	-	-	-
Zn (Diss)	ug/l	26	-	-	-
MBAS	mg/l	0.02	-	-	-

* Not known if these represent total or dissolved iron.

TABLE 5

SUPPLEMENTAL GROUNDWATER SAMPLING PROGRAM

Sample Number	Well Name	USGS Well Number	Parameters Sampled
P-1	City, Hoffman #1 & #2	25/43-4B1	A-B-C
P-3	City, Ray St. #1 & #2	25/43-22F	A-B
P-4	Modern #8	25/44-17A1	A-B
P-5	Model #1	25/44-21L	A-B
P-6	Vera #5	25/44-26D1	A-B
P-7	CID #2A, 2B & 2C	25/45-18R	A
P-10	WWP #3-6	26/43-3Q	A-B-C
P-11	Whitworth #2A	26/43-20D	A-B-C
P-12	N. Spokane # 1 & #2	26/43-28H	A-B-C
P-13	CID #6A, 6B & 6C	25/45-4C	A
P-14	MOAB #1	26/45-24P	A
P-W	USBR, Post Falls #1	5/51-28N	A
P-X	Kaiser Eastgate	25/44-2Q1	A-B-E
P-Y	Spokane Cold Storage	25/42-13B1	A
P-Z	Kaiser Mead	26/43-16F2	A-B-C-E
B-1	Airway Heights #3	25/41-26H	B-D
B-2	Spangle #2	22/43-4F	B-D
B-3	Latah #1	21/45-30B	B-D
O-1	Chattaroy Valley Mobile Estates	28/43	B-D
O-2	Diamond Lake (Degestrom Well)		B-D
O-3	Rivilla #1	26/43-6G1	B-D

Identification of Parameters Sampled

A - Full spectrum of chemical parameters per USGS-EPA program
B - Total Fecal Coliform
C - Hexane Extractables
D - Detergents (where A is not run, A includes detergents)
E - Aluminum

TABLE 6

RESULTS OF GROUNDWATER SAMPLING PROGRAM

										Well Identificatio		
Parameter	Units	P-1 25/43-4B1*	P-3 25/43-22F*	P-4 25/44-17A1*	P-5 25/44-21L*	P-6 25/44-26D1*	P-7 25/45-18R*	P-10 26/43-3Q*	P-11 26/43-20D*	P-12 26/43-28H*	P-13 25/45-4C*	P-14 26/45-2
Conductivity	µmhos/cm	291	348	270	259	235	170	265	235	252	259	167
Residue (180°C)	mg/l	176	226	539	179	160	121	184	149	146	165	113
Residue	TON/AFT	.24	.31	.73	.24	.22	.16	.25	.20	.20	.22	.15
pH	--	7.6	7.5	8.1	7.75	7.9	7.85	7.8	7.5	8.2	7.9	7.7
Temperature	°C	11.5	12.0	9.5	12.0	11.5	11.0	12.5	11.5	11.0	9.0	9.0
Hardness ($CaCO_3$)	mg/l	154	178	152	132	132	88	148	128	136	140	116
NH_3-N	mg/l	<.056	<.056	<.056	<.056	<.056	<.056	<.056	<.056	<.056	<.056	<.056
NO_2-N	mg/l	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
NO_3-N	mg/l	1.1	2.8	1.2	2.2	1.9	1.2	1.5	1.3	1.5	1.1	0.17
Kjeldahl Nitrogen	mg/l	<.28	<.28	<.28	<.28	<.28	<.28	<.28	<.28	<.28	<.28	<.28
PO_4-P (Total)	mg/l	.028	.037	.032	.028	.030	.026	.040	.086	.032	.032	.032
PO_4-P (Ortho)	mg/l	.028	.037	.032	.022	.024	.022	.040	.084	.026	.024	.032
Chlorine	mg/l	2.0	7.0	0.5	2.0	1.0	<0.5	3.0	2.5	4.0	<0.5	0.5
Aluminum	µg/l	--	--	--	--	--	--	--	--	--	--	--
Arsenic	µg/l	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Cadmium	µg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chromium	µg/l	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Copper	µg/l	200	<5	<5	<10	<5	330	<5	<5	<5	50	<5
Iron	µg/l	10	<10	<10	<10	10	<10	<10	<10	10	10	<10
Lead	µg/l	<10	<10	<10	<10	<10	30	<10	<10	<10	<10	<10
Manganese	µg/l	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Mercury	µg/l	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Zinc	µg/l	<5	30	<5	20	<5	540	10	120	32	23	6
MBAS	mg/l	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Oil & Grease	mg/l	6.1	--	--	--	--	--	5.0	5.5	6.3	--	--
Total Coliform	#/100ml	<1	<1	<1	4	<1	--	<1	<1	4	--	<1
Fecal Coliform	#/100ml	<1	<1	<1	<1	<1	--	<1	<1	<1	--	<1

*USGS number.

TABLE 6

F GROUNDWATER SAMPLING PROGRAM

Well Identification													
P-11 /43-20D*	P-12 26/43-28H*	P-13 25/45-4C*	P-14 26/45-24P	P-W 5/51-28N*	P-X 25/44-2Q1*	P-Y 25/42-13B1*	P-Z 26/43-16F*	B-1 25/41-26H*	B-2 22/43-4F*	B-3 21/45-30B*	O-1 28/43*	O-2	O-3 26/43-6G1*
235	252	259	167	268	767	353	300	--	--	--	--	--	--
149	146	165	113	170	537	233	165	--	--	--	--	--	--
.20	.20	.22	.15	.23	.73	.32	.22	--	--	--	--	--	--
7.5	8.2	7.9	7.7	7.95	7.75	7.48	7.6	--	--	--	--	--	--
11.5	11.0	9.0	9.0	10.0	11.0	12.5	12.0	--	--	--	--	--	--
128	136	140	116	144	228	164	146	--	--	--	--	--	--
<.056	<.056	<.056	<.056	<.056	<.056	<.056	<.056	--	--	--	--	--	--
<.002	<.002	<.002	<.002	<.002	.039	<.002	<.002	--	--	--	--	--	--
1.3	1.5	1.1	0.17	1.3	<.01	1.1	1.7	--	--	--	--	--	--
<.28	<.28	<.28	<.28	<.28	1.12	<.28	<.28	--	--	--	--	--	--
.086	.032	.032	.032	.032	.032	.054	.026	--	--	--	--	--	--
.084	.026	.024	.032	.030	.024	.038	.024	--	--	--	--	--	--
2.5	4.0	<0.5	0.5	0.5	130	22.5	9.5	--	--	--	--	--	--
--	--	--	--	--	<20	--	<20	--	--	--	--	--	--
<6	<6	<6	<6	<6	<6	<6	<6	--	--	--	--	--	--
<5	<5	<5	<5	<5	<5	<5	<5	--	--	--	--	--	--
<5	<5	<5	<5	<5	10	<5	<5	--	--	--	--	--	--
<5	<5	50	<5	<5	120	<5	10	--	--	--	--	--	--
10	10	10	<10	<10	20	<10	<10	--	--	--	--	--	--
10	<10	<10	<10	<10	20	<10	<10	--	--	--	--	--	--
10	<10	<10	<10	<10	<10	<10	<10	--	--	--	--	--	--
<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	--	--	--	--	--	--
120	32	23	6	<5	96	<5	<5	--	--	--	--	--	--
<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	.07	<.05	<.05	<.05	<.05
5.5	6.3	--	--	--	--	--	5.5	--	--	--	--	--	--
<1	4	--	<1	--	<1	--	<1	<1	<1	<1	2	<1	<1
<1	<1	--	<1	--	<1	--	<1	<1	<1	<1	<1	<1	<1

TABLE 6

RESULTS OF GROUNDWATER SAMPLING PROGRAM

2

TABLE 7

SUMMARY OF GROUND WATER QUALITY IN THE STUDY AREA

Parameter	Units	Primary Aquifer Avg.	Primary Aquifer Std. Dev.	Primary Aquifer Samples	Basalt Aquifer Avg.	Basalt Aquifer Std. Dev.	Basalt Aquifer Samples	Little Spokane Basin Aquifer Avg.	Little Spokane Basin Aquifer Std. Dev.	Little Spokane Basin Aquifer Samples	Other Aquifers Avg.	Other Aquifers Std. Dev.	Other Aquifers Samples
Conductivity	µmhos(cm)	283	56	213	263	90	95	292	106	16	285	145	19
Residue (180°C)	mg/1	176	54	51	177	34	64	-	-	-	-	-	-
Residue	TON/AFT	.24	.07	60	0.24	0.05	64	-	-	-	-	-	-
pH		7.7	0.6	210	7.7	0.3	95	7.7	0.4	16	7.4	0.4	19
Temp.	°C	10.7	1.7	81	14.0	3.3	56	-	-	-	-	-	-
D.O.	mg/1	8.1	1.1	8	-	-	-	-	-	-	-	-	-
Hardness ($CaCO_3$)	mg/1	156	39	214	108	38	97	151	64	16	136	72	19
NH_3-N	mg/1	<.023	0.018	61	-	-	-	-	-	-	-	-	-
NO_2-N	mg/1	.002	.002	61	-	-	-	-	-	-	-	-	-
NO_3-N	mg/1	1.506	1.161	62	1.686	2.884	96	1.418	1.624	16	1.046	1.504	19
Kjeldahl Nitrogen(N)	mg/1	< 0.144	0.147	61	-	-	-	-	-	-	-	-	-
PO_4-P (Total)	mg/1	0.018	0.016	62	0.088	0.121	31	0.095	0.082	16	0.115	0.272	19
PO_4-P (Ortho)	mg/1	0.014	0.016	61	0.070	0.099	2	-	-	-	-	-	-
Cl	mg/1	4.6	3.6	210	5.1	7.0	96	3.4	4.5	16	8.6	10.3	19
Al	ug/1	-	-	-	-	-	-	-	-	-	-	-	-
As	ug/1	5	9	61	-	-	-	-	-	-	-	-	-
Cd	ug/1	< 1	2	61	-	-	-	-	-	-	-	-	-
Cr	ug/1	< 1	2	61	-	-	-	-	-	-	-	-	-
Cu	ug/1	<15	49	61	-	-	-	-	-	-	-	-	-
Fe (Diss)	ug/1	24	29	61	-	-	-	-	-	-	-	-	-
Fe (Total)	ug/1	169	356	146	140*	178	88	100*	100	16	161	167	19
Pb (Diss)	ug/1	< 4	6	55	-	-	-	-	-	-	-	-	-
Pb (Total)	ug/1	19	8	20	-	-	-	-	-	-	-	-	-
Mn	ug/1	7	10	213	-	-	-	-	-	-	-	-	-
Hg (Total)	ug/1	1	4	73	-	-	-	-	-	-	-	-	-
Zn	ug/1	34	73	62	-	-	-	-	-	-	-	-	-
MBAS	mg/1	0.03	0.03	57	< 0.06	0.01	3	< .05	0	3	-	-	-
Oil & Grease	mg/1	5.7	0.6	4	-	-	-	-	-	-	-	-	-
Total Coliform	#/100 ml	< 2	1	9	< 1	0	3	< 1	1	3	-	-	-
Fecal Coliform	#/100 ml	< 1	0	9	< 1	0	3	< 1	0	3	-	-	-

* Data do not permit definition as to whether dissolved or total

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/42-3H1 →	→	25/42-13B1 →	→	→
Conductivity	umhos/cm	296	275	336	335	388
Residue (Total)	mg/1	179			0.26	029
Residue (180°C)	mg/1			179	188	210
Residue, Calculated	mg/1					
Residue Loading	TON/AFT			0.24		
pH	--	8.2		7.4	7.7	7.9
Temperature	°C	8.2	11.5	12.4	12.0	12.0
Dissolved Oxygen	mg/1		5.9			
Hardness ($CaCO_3$)	mg/1	145	134	160	150	170
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1			0.01	0.01	0.01
NO_2 -N	mg/1			0.002	0 001	0.002
NO_3 -N	mg/1			1.7	1.4	1.3
Kjeldahl-N	mg/1			0.12	0.16	007
PO_4 -P (Total)	mg/1			0.06	0.06	0.10
PO_4 -P (Ortho)	mg/1			0.05	0.06	0.09
Chloride	mg/1	4		4	12.0	24.0
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1			0	6.0	2.0
Cadmium	µg/1			1.0	00	0
Chromium	µg/1			0	00	0
Copper	µg/1			2.0	4.0	3.0
Iron (Dis)	µg/1			30	110	30
Iron (Tot)	µg/1					
Lead (Dis)	µg/1			0	40	0
Lead (Tot)	µg/1					
Manganese	µg/1			0	0	0
Mercury	µg/1			0	0	0
Zinc	µg/1			10	20	30
MBAS	mg/1			0.00	0.03	0 02
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →	→	USGS-EPA →	→	→
Sample Date		70-10-14	72-08-08	73-06-07	72-10-16	72-12-7
Owner		City of Spokane Baxter #1 →	→	Spokane Cold Storage →	→	→

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/42-13B1	25/43-11G1	——→	25/43-11-G4	25/43-12H1
Conductivity	umhos/cm	410	315			296
Residue (Total)	mg/l	031				164
Residue (180°C)	mg/l	231				
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	--	7.5				7.6
Temperature	°C	12.0	9.0	8.9		5.6
Dissolved Oxygen	mg/l		8.2	9.2		
Hardness ($CaCO_3$)	mg/l	180	156			154
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l	0.02				
NO_2 -N	mg/l	0.003				
NO_3 -N	mg/l	1.6				
Kjeldahl-N	mg/l	0.25				
PO_4 -P (Total)	mg/l	0.007				
PO_4 -P (Ortho)	mg/l	0.006				
Chloride	mg/l	24				2
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l	1				
Cadmium	µg/l	0				
Chromium	µg/l	0				
Copper	µg/l	8				
Iron (Dis)	µg/l	10				
Iron (Tot)	µg/l		5	20	20	0
Lead (Dis)	µg/l	1				
Lead (Tot)	µg/l			50	25	
Manganese	µg/l	140		40	20	0
Mercury	µg/l	0	1.3	0.2K	0.2K	
Zinc	µg/l	30				
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	Storet ———			——→
Sample Date		74-03-20	72-[illegible]-2	73-[illegible]-15	73-01-15	71-04-01
Owner		SPOKANE CO. [illegible]	C[illegible] OF [illegible]OKANE W[illegible] F[illegible] #1	——→	S[illegible] N[illegible] F[illegible] #2	ORCHARD AVE #1

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/43-12H1				→
Conductivity	umhos/cm	360	300	300	264	292
Residue (Total)	mg/1	221	145	306	140	172
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.6	7.6	7.1	7.5	7.5
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	204	148	316	112	164
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	4	3	9	2	2
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	200	60	20	40	180
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	9	9	9	0	0
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		71-09-17	71-10-14	71-11-15	71-12-13	72-01-18
Owner		ORCHARD AVE #1	→			

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-12H1	→	→	→	→
Conductivity	umhos/cm	312	300	326	310	308
Residue (Total)	mg/1	179	172	211	194	304
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	8.1	7.7	8.0	8.3	8.4
Temperature	°C				10.0	
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	176	148	188	154	194
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5	3	6	2	11
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	80	160	180	120	90
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	3	6	6	0	300
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		72-02-14	72-03-31	72-0[illegible]-1[illegible]	72-05-22	72-06-12
Owner		ORCHARD AVE #1 →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-12M1 →				
Conductivity	umhos/cm	330	300	320	310	
Residue (Total)	mg/1	183	158	248	174	
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.7	7.8	7.9	7.4	
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	204	156	324	156	
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	10	4	4	2	
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	300	20	80	100K	10
Lead (Dis)	µg/1				20	30
Lead (Tot)	µg/1					
Manganese	µg/1	6	18	6	2	2
Mercury	µg/1				18.8	0.2
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		72-07-17	72-08-14	72-09-14	72-09-14	73-01-15
Owner		ORCHARD AVE #1 →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/43-13M1	→	→	→	
Conductivity	umhos/cm	270	265	261	268	
Residue (Total)	mg/1	0.21	0.23	0.19	0.2	
Residue (180°C)	mg/1	154	170	140	149	
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.7	8.2	8.2	7.9	
Temperature	°C	10.0	17.0	18.5	10.2	
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	140	130	130	140	
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.02	0.02	0.01	0.03	
NO_2 -N	mg/1	0	0.003	0.003	0.001	
NO_3 -N	mg/1	0.84	1.00	1.00	0.90	
Kjeldahl-N	mg/1	0.05	0.04	0.03	0.84	
PO_4 -P (Total)	mg/1	0.011	0.006	0.031	0.007	
PO_4 -P (Ortho)	mg/1	0.007	0.005	0.025	0.005	
Chloride	mg/1	1.7	2.1	1.4	2.2	
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	29	5	2	2	
Cadmium	µg/1	1.0	0	0	0	
Chromium	µg/1	0	0	0	0	
Copper	µg/1	20	30	50	50	
Iron (Dis)	µg/1	130	10	150	60	
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	3	3	4	17	
Lead (Tot)	µg/1					
Manganese	µg/1	0	10	30	20	
Mercury	µg/1	0.1	0	0	0	
Zinc	µg/1	50	20	90	70	
MBAS	mg/1	0	0.01	0	0	
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→	→	→	
Sample Date		73-06-29	73-09-25	73-12-17	74-0322	
Owner		WWP #1-3	→	→	→	

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-14K1	→	→	→	25/43-23A1
Conductivity	umhos/cm	235	236	238	235	284
Residue (Total)	mg/1	0.17	0.21	0.19	0.18	167
Residue (180°C)	mg/1	126	152	136	130	
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.6	8.0	8.1	7.8	8.3
Temperature	°C	11.6	11.5	11.0	10.2	7.3
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	110	120	120	120	120
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.01	0.01	0.01	0.02	
NO_2 -N	mg/1	0.001	0.002	0.002	0.002	
NO_3 -N	mg/1	1.1	1.1	0.9	1.1	
Kjeldahl-N	mg/1	0.05	0.04	0.02	0.12	
PO_4 -P (Total)	mg/1	0.012	0.008	0.010	0.005	
PO_4 -P (Ortho)	mg/1	0.003	0.005	0.004	0.003	
Chloride	mg/1	1.5	2.1	1.8	2.3	5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	0	0	0	0	
Cadmium	µg/1	1.0	0	0	0	
Chromium	µg/1	0	0	0	0	
Copper	µg/1	6.0	4.0	3.0	4	
Iron (Dis)	µg/1	50	30	0	20	
Iron (Tot)	µg/1					430
Lead (Dis)	µg/1	4	3	1	1	
Lead (Tot)	µg/1					
Manganese	µg/1	0	0	0	14	23
Mercury	µg/1	0.1	0	0	0	
Zinc	µg/1	10	40	0	20	
MBAS	mg/1	0	0	0.03		
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→	→	→	Storet
Sample Date		73-06-27	73-09-25	73-12-17	74-03-20	70-05-07
Owner		ACME CONCRETE	→	→	→	WWP #1-5A

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/43-231A	→	→	→	→
Conductivity	umhos/cm	234	350	280	310	300
Residue (Total)	mg/1	167	1[illegible]4	193	225	175
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	—	7.5	7.9	7.7	7.6	6.9
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	156	144	160	220	154
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5	6	4	5	7
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	140	160	60	140	320
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	15	15	2	6	9
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		71-07-21	71-09-16	71-10-13	71-11-15	71-12-13
Owner		WWP #1-5A →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/43-23IA	→	→	→	→
Conductivity	umhos/cm	320	330	306	314	310
Residue (Total)	mg/1	249	169	179	210	181
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	—	7.8	8.0	8.0	8.1	7.9
Temperature	°C					12.2
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	200	128	176	208	166
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5	7	5	5	7
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	440	160	160	0	40
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	12	6	0	0	6
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		72-01-18	72-02-14	72-03-03	72-04-18	72-05-11
Owner		WWP #1-5A →				

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-33A1				
Conductivity	umhos/cm	300	300	298	280	310
Residue (Total)	mg/1	179	173	202	191	218
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	8.3	7.6	8.0	8.0	7.5
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	160	164	188	152	158
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	7	11	5	4	4
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	220	740	120	700	100K
Lead (Dis)	µg/1					40
Lead (Tot)	µg/1					
Manganese	µg/1	3	6	12	15	3
Mercury	µg/1					6.3
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-06-16	72-07-24	72-08-25	72-[illegible]-14	72-09-14
Owner		WWP #1-5A				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-23A1	25/43-23A2	→		→
Conductivity	umhos/cm		292	400	345	310
Residue (Total)	mg/l		176	178	179	206
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	—		8.1	7.7	8.0	7.2
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l		152	148	180	208
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l		8	7	5	5
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	30				
Lead (Dis)	µg/l	15				
Lead (Tot)	µg/l		0	0	300	10
Manganese	µg/l	2	6	6	6	6
Mercury	µg/l	0.2K				
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		73-01-15	71-07-21	71-09-16	71-10-13	71-11-15
Owner		WWP #1-5A	WWP #1-5B	→		

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-23A2				→
Conductivity	umhos/cm	290	340	340	280	292
Residue (Total)	mg/l	174	222	218	181	192
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	---	7.7	7.1	7.9	8.2	7.9
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	156	200	212	148	156
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	4	9	6	5	5
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	280	60	40	120	60
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l	6	0	6	6	6
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		71-12-13	72-01-18	72-02-14	72-03-31	72-04-18
Owner		WWP #1-5B →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-23A2				
Conductivity	umhos/cm	310	280	300	288	300
Residue (Total)	mg/l	181	165	190	218	229
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	---	7.9	7.9	7.9	7.9	8.2
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	165	154	180	204	204
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	6	8	11	7	8
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	220	220	100	100	30
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l	6	0	6	16	6
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-05-11	72-06-16	72-07-24	72-08-23	72-09-14
Owner		WWP #1-5B				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-23M2	→	25/43-24G1	→	→
Conductivity	umhos/cm	310		400	380	368
Residue (Total)	mg/1			226	222	181
Residue (180°C)	mg/1					
Residue, Calculated	mg/1			181		
Residue Loading	TON/AFT					
pH	--	7.4		7.7	7.8	7.6
Temperature	°C			5.0		
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	156		190	196	200
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	4		4	6	8
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	100K	20			
Iron (Tot)	µg/1	15		0	0	0
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	2K		0	9	12
Mercury	µg/1	4.3	0.2K			
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet	→	→	→	→
Sample Date		72-09-14	73-01-15	70-12-21	71-10-18	71-11-15
Owner		WWP #1-5B	→	E. SPOKANE #1	→	→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-24G1	→	→	→	→
Conductivity	umhos/cm	420	400	380	380	410
Residue (Total)	mg/l	212	219	248	235	248
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	—	7.8	7.8	8.0	8.0	8.0
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	224	240	236	212	240
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	13	9	6	7	8
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	340	240	380	460	0
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l	9	0	6	3	0
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet	→	→	→	→
Sample Date		71-12-13	72-01-18	72-02-14	72-03-31	72-04-18
Owner		E. SPOKANE #1	→	→	→	→

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-24G1				
Conductivity	umhos/cm	371	400	420	380	360
Residue (Total)	mg/1	249	285	217	240	246
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	8.3	7.3	7.8	7.8	7.7
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	216	260	200	216	192
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	8	11	14	8	7
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	40	360	0	300	140
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	9	0	3	6	9
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-05-11	72-06-12	72-07-7	72-08-14	72-09-14
Owner		E. SPOKANE #1				

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/43-24G1	25/44-1J1	→		→
Conductivity	umhos/cm	410	284	197	325	293
Residue (Total)	mg/1	236				
Residue (180°C)	mg/1		160	160	177	160
Residue, Calculated	mg/1					
Residue Loading	TON/AFT		0.22	0.22	0.24	0.22
pH	--	7.3	7.7	7.9	7.9	7.6
Temperature	°C		10.6	10.5	10.0	9.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	199	140	150	160	140
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1		0.01	0.01	0.01	0.03
NO_2 -N	mg/1		0.001	0.003	0.002	0.001
NO_3 -N	mg/1		0.81	0.71	2.10	0.82
Kjeldahl-N	mg/1		0.05	0.03	0.08	0.40
PO_4 -P (Total)	mg/1		0.010	0.008	0.008	0.005
PO_4 -P (Ortho)	mg/1		0.002	0.007	0.008	0.003
Chloride	mg/1	6	1.5	1.1	1.4	0.9
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1		3	4	4	3
Cadmium	µg/1		0	0	0	0
Chromium	µg/1		0	0	0	0
Copper	µg/1		10	16	2	5
Iron (Dis)	µg/1		60			
Iron (Tot)	µg/1	100				
Lead (Dis)	µg/1					
Lead (Tot)	µg/1	15				
Manganese	µg/1	3				
Mercury	µg/1	6.5				
Zinc	µg/1					
MBAS	mg/1		0	0.06	0.06	0.01
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet	USGS- EPA →			
Sample Date		72-09-14	73-06-27	73-07-25	73-12-17	74-03-20
Owner		E. SPOKANE #1	SPOKANE IND. PK #2	→		

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/44-2Q1	→	→	→	25/44-7C1
Conductivity	umhos/cm	336	320	357	590	309
Residue (Total)	mg/l					
Residue (180°C)	mg/l	175	174	197	329	169
Residue, Calculated	mg/l					
Residue Loading	TON/AFT	0.24	0.24	0.27	0.45	0.23
pH	--	7.6	7.9	7.9	7.5	7.6
Temperature	°C	10.2	9.5	9.5	9.5	9.6
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	150	150	170	190	160
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l	0.01	0.01	0.02	0.69	0.02
NO_2 -N	mg/l	0	0.002	0.003	0.013	0
NO_3 -N	mg/l	2.0	1.4	3.1	5.4	0.84
Kjeldahl-N	mg/l	0.08	0.05	0.06	0.91	0.04
PO_4 -P (Total)	mg/l	0.008	0.004	0.020	0.004	0.009
PO_4 -P (Ortho)	mg/l	0.003	0.004	0.018	0.003	0.007
Chloride	mg/l	4.4	3.0	7.3	6.0	1.7
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l	4	6	3	2	6
Cadmium	µg/l	1	0	0	0	1
Chromium	µg/l	0	0	0	30	0
Copper	µg/l	9	3	4	4	5
Iron (Dis)	µg/l	40	20	60	10	30
Iron (Tot)	µg/l					
Lead (Dis)	µg/l	3	5	0	1	0
Lead (Tot)	µg/l					
Manganese	µg/l	0	0	0	0	0
Mercury	µg/l	0	0.1	0	0	0.1
Zinc	µg/l	360	60	80	90	10
MBAS	mg/l	0.03	0.05	0.02	0.10	0
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→	→	→	→
Sample Date		73-06-27	73-09-25	73-12-18	73-03-20	73-06-27
Owner		KAISER (TRENTWOOD) EAST GATE	→	→	→	ORCHARD AVE #2

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/44-761	→	→	25/44-1802	→
Conductivity	umhos/cm	306	315	321	282	278
Residue (Total)	mg/1					
Residue (180°C)	mg/1	206	175	172	150	193
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.28	0.24	0.23	0.02	0.06
pH	—	8.1	8.0	7.7	7.6	8.1
Temperature	°C	9.0	8.0	9.6	10.6	10.5
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	150	160	160	140	140
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.02	0.01	0.01	0.01	0.01
NO_2 -N	mg/1	0.002	0.003	0.001	0	0.002
NO_3 -N	mg/1	0.76	1.00	1.2	1.2	1.1
Kjeldahl-N	mg/1	0.02	0.10	0.04	0.03	0.07
PO_4 -P (Total)	mg/1	0.011	0.016	0.014	0.010	0.011
PO_4 -P (Ortho)	mg/1	0.011	0.012	0.008	0.005	0.006
Chloride	mg/1	2.1	1.9	2.2	2.0	2.5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	1	6	3	2	2
Cadmium	µg/1	0	1	0	0	0
Chromium	µg/1	0		0	0	0
Copper	µg/1	2	3	3	6	4
Iron (Dis)	µg/1	10	30	20	40	20
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	1	0	1		
Lead (Tot)	µg/1					
Manganese	µg/1	10	0	14	10	0
Mercury	µg/1	0	0	0	0	0
Zinc	µg/1	20	0	30	10	40
MBAS	mg/1	0	0.03	0	0	0.08
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→	→	→	→
Sample Date		73-09-25	73-12-18	73-04-19	73-06-27	73-09-15
Owner		ORCHARD AVE #2	→	→	WU #1-4	→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/44-18D2	25/44-19D1	→		→
Conductivity	umhos/cm	270	369	390	373	394
Residue (Total)	mg/1					
Residue (180°C)	mg/1	147	211	206	207	226
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.20	0.29	0.28	0.28	0.31
pH	--	8.0	7.5	7.7	7.8	7.7
Temperature	°C	11.0	11.9	11.5	11.5	11.2
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	130	190	180	180	190
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.01	0.04	0.01	0.01	0.01
NO_2 -N	mg/1	0.003	0	0.001	0.002	0.001
NO_3 -N	mg/1	1.1	2.8	3.0	2.6	2.2
Kjeldahl-N	mg/1	0.06	0.07	0.23	0.07	0.13
PO_4 -P (Total)	mg/1	0.010	0.023	0.025	0.026	0.026
PO_4 -P (Ortho)	mg/1	0.007	0.021	0.009	0.023	0.018
Chloride	mg/1	1.8	6.0	11.0	6.0	7.1
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	4	4	6	6	4
Cadmium	µg/1	0	1	0	0	0
Chromium	µg/1	0	0	0	0	0
Copper	µg/1	3	8	2	5	8
Iron (Dis)	µg/1	10	10	30	10	10
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					1
Lead (Tot)	µg/1					
Manganese	µg/1	0	0	0	10	36
Mercury	µg/1	0	0.1	0	0	0
Zinc	µg/1	0	20	10	10	20
MBAS	mg/1	0.06	0	0.04	0.04	0.08
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→			
Sample Date		73-12-18	73-06 27	75-09-26	73-12-18	74-03-20
Owner		WWP #1-4	EDGECLIFF SANITORIUN	→		

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/44-15E2 →				
Conductivity	umhos/cm	249	360	240	268	256
Residue (Total)	mg/1	138	168	169	148	144
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	8.3	7.6	7.5	7.8	7.7
Temperature	°C	10.0				
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	108	136	142	148	134
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	0	14	4	4	8
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	1080	130	10	0	320
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	29	0	6	6	9
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		70-05-12	71-09-14	71-10-14	71-11-16	71-12-14
Owner		MODERN ELECTRIC #1 →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/44-15E2	→			→
Conductivity	umhos/cm	240	240	260	240	280
Residue (Total)	mg/l	106	156	167	184	158
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	---	7.0	7.3	7.8	7.8	7.9
Temperature	°C					10.0
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	172	136	156	168	156
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	4	1	0	4	4
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	180	320	140	200	140
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l	18	3	0	19	6
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet	→			→
Sample Date		72-01-17	72-02-16	72-03-28	72-04-19	72-05-11
Owner		MODERN ELECTRIC #1	→			→

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	254-522	→	→	→	→
Conductivity	umhos/cm	300	288	252	260	260
Residue (Total)	mg/1	177	135	165	151	146
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.4	7.5	7.9	7.6	7.5
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	160	116	156	140	135
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5	8	3	4	6
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	280	20	200	30	100k
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					[illegible]
Manganese	µg/1	3	6	3	16	3
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-06 14	72 07-11	72-08 33	72-09 14	72 09 14
Owner		MODERN ELECTRIC #1	→	→	→	→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/44-26D1				
Conductivity	umhos/cm	340	340	370	340	346
Residue (Total)	mg/l	212	188	260	196	186
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	--	7.6	7.6	7.3	7.8	7.7
Temperature	°C	10.0				
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	174	156	244	172	178
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	3	8	10	6	3
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	0	200	40	20	220
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l	6	0	3	29	6
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		70-11-04	71-08-09	71-09-14	71-10-13	71-11-16
Owner		VERA I.D #5				

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number 25/44-26D1				
Conductivity	umhos/cm	326	370	340	310	324
Residue (Total)	mg/l	171	207	254	181	208
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	---	7.1	8.3	8.2	7.9	7.9
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	164	200	264	172	208
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	0.5	5	3	2	3
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	300	60	160	100	10
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l	9	15	6	3	0
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		71-12-13	72-01-17	72-02-14	72-03-31	72-04-18
Owner		VERA I.D #5				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number 25/44-26D1				
Conductivity	umhos/cm	200	326	386	332	326
Residue (Total)	mg/1	134	217	195	215	180
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	8.0	8.0	7.9	7.9	6.8
Temperature	°C	11.0				
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	136	192	180	232	182
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3	4	11	3	4
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	20	200	140	60	60
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	60	9	9	3	6
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-05-22	72-06-12	72-07-17	72-08-23	72-09-14
Owner		VERA ID #5				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/44-26D1	25/44-27E1	→		→
Conductivity	umhos/cm	350	260	384	284	276
Residue (Total)	mg/1	223	140	244	194	147
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.1	7.6	7.8	7.8	6.5
Temperature	°C		10.0			
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	183	108	248	158	148
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2	3	9	8	4
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	100K	0	200	120	300
Lead (Dis)	µg/1					
Lead (Tot)	µg/1	15				
Manganese	µg/1	2	3	6	9	9
Mercury	µg/1	4.2				
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		72-09-14	70-09-29	71-09-14	71-10-14	71-11-16
Owner		VERA I.D #5	Modern Elect. #9	→		

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	25/44-27E1				
Conductivity	umhos/cm	300	300	234	250	268
Residue (Total)	mg/1	178	182	138	156	223
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	8.0	8.3	7.9	7.8	7.2
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	144	152	144	152	208
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	28	20	2	2	0
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	0	100	100	220	120
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	18	6	3	3	3
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		71-12-14	72-01-17	72-02-16	72-03-28	72-04-19
Owner		Modern Elect #9 →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/44-27E1				
Conductivity	umhos/cm	284	260	304	276	300
Residue (Total)	mg/1	169	173	185	172	161
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	8.1	8.0	7.3	7.8	7.5
Temperature	°C	12.8				
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	170	148	140	172	152
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5	5	12	5	5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	140	10	380	40	100
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	9	0	6	9	6
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Sample Date		72-05-11	72-06-19	72-07-17	72-08-23	72-09-14
Owner		Modern Elect #9				

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/44-27E1	25/44-29A1	→		→
Conductivity	umhos/cm	300	125	384	340	350
Residue (Total)	mg/l	186	199	220	202	220
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	--	7.4	7.9	7.9	7.9	7.6
Temperature	°C		10.0			
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	153	142	196	192	200
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	3	3	7	7	5
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	100K	140	0	120	40
Lead (Dis)	µg/l					
Lead (Tot)	µg/l	15				
Manganese	µg/l	2K	6	9	0	3
Mercury	µg/l	3.8				
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Sample Date		72-09-14	70-09-23	71-09-14	71-10-13	71-11-15
Owner		Modern Elect #9	WWP #2-4	→		→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/44-29A1 →				
Conductivity	umhos/cm	330	330	340	300	300
Residue (Total)	mg/1	238	192	197	193	155
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	—	7.8	8.3	8.2	7.8	8.0
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	232	188	200	172	172
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	9	6	5	4	3
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	140	180	420	360	9
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	36	0	6	3	0
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		71-12-13	72-01-18	72-02-14	72-03-31	72-04-18
Owner		W.W.P #2-4 →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/44-29A1				
Conductivity	umhos/cm	310	320	368	350	
Residue (Total)	mg/l	235	192	192	219	
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	--	8.1	7.9	8.0	7.6	
Temperature	°C	10.0				
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	178	176	188	173	
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l					
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	6	7	12	4	
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	60	180	260	100K	15
Lead (Dis)	µg/l					
Lead (Tot)	µg/l				420	20
Manganese	µg/l				2	2
Mercury	µg/l				9.3	0.2K
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-05-11	72-06-16	72-07-17	72-09-14	73-01-15
Owner		WWP #2-4				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number 25/45-15D1	→	→	→	→
Conductivity	umhos/cm	236	270	260	228	250
Residue (Total)	mg/1	163	136	196	134	159
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.3	8.1	7.4	7.7	7.7
Temperature	°C	11.7				
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	156	132	204	112	136
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1		7	5	4	5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	120		100	140	50
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	4	15	9		3
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet	→	→	→	→
Sample Date		71-07-21	71-08-18	71-09-16	71-10-13	71-11-10
Owner		Holiday Hills	→	→	→	→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/45-15D1 →				
Conductivity	umhos/cm	216	248	248	7	184
Residue (Total)	mg/1	127	97	164	156	176
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.2	7.9	8.2		7.3
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	124	94	148	118	196
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2	4	5	2	2
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	340	20	80	60	80
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	0		9	6	0
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		71-12-13	72-01-18	72-02-[illegible]	72-03-28	72-04-18
Owner		Holiday Hills →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number 25/45-15D1				
Conductivity	umhos/cm	192	242	248	246	256
Residue (Total)	mg/1	124	138	141	149	144
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.8	8.1	7.6	8.1	7.5
Temperature	°C	11.7				
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	120	124	136	144	140
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	7	6	9	3	5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1	300	4000	20	300	80
Manganese	µg/1	9	6	3	3	6
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-05-10	72-06-19	72-07-24	72-08-14	72-09-14
Owner		Holiday Hills				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number 25/45-15D1 →				
Conductivity	umhos/cm	260		266	259	263
Residue (Total)	mg/1	181				
Residue (180°C)	mg/1			158	157	154
Residue, Calculated	mg/1					
Residue Loading	TON/AFT			0.21	0.21	0.21
pH	—			7.6	8.1	8.1
Temperature	°C			12.0	12.0	12.0
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	125		120	120	120
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1			0.03	0.01	0.01
NO_2 -N	mg/1			0.000	0.002	0.002
NO_3 -N	mg/1			2.8	1.5	2.0
Kjeldahl-N	mg/1			0.06	0.05	0.04
PO_4 -P (Total)	mg/1			0.021	0.023	0.073
PO_4 -P (Ortho)	mg/1			0.021	0.022	0.073
Chloride	mg/1	2		2.3	2.3	2.5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1			5	6	5
Cadmium	µg/1			1	0	0
Chromium	µg/1			0	0	0
Copper	µg/1			3	6	3
Iron (Dis)	µg/1			10	10	0
Iron (Tot)	µg/1	100K	15			
Lead (Dis)	µg/1			1	2	0
Lead (Tot)	µg/1	20	20			
Manganese	µg/1	2	2	10	0	0
Mercury	µg/1	20.4	0.2K	0.1	0	0
Zinc	µg/1			10	50	0
MBAS	mg/1			0.00	0.04	0.02
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)		72-09-14	73-01-15	73-06-28	73-09-25	73-12-18
Source		Storet →	→	USGS-EPA →	→	→
Sample Date						
Owner		Holiday Hills →	→	→	→	→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/45-15D1	26/42-1J1(S) →			
Conductivity	umhos/cm	242	350		367	360
Residue (Total)	mg/l					
Residue (180°C)	mg/l	143			200	186
Residue, Calculated	mg/l					
Residue Loading	TON/AFT	.19			0.27	0.25
pH	—	7.8	7.5		7.6	8.0
Temperature	°C	11.8	10.0	10.0	10.8	11.0
Dissolved Oxygen	mg/l		8.7	9.3		
Hardness ($CaCO_3$)	mg/l	120	179		180	180
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l	0.03			0.02	0.02
NO_2 -N	mg/l	0.002			0.002	0.002
NO_3 -N	mg/l	1.3	2.2		2.5	2.5
Kjeldahl-N	mg/l	0.56			0.05	0.21
PO_4 -P (Total)	mg/l	0.023	0.01		0.009	0.048
PO_4 -P (Ortho)	mg/l	0.021			0.005	0.043
Chloride	mg/l	2.6			5.8	5.9
Sulfate	mg/l					
Fluoride	mg/l					
Aluminum	µg/l					
Arsenic	µg/l	2			1	9
Cadmium	µg/l	0			1	0
Chromium	µg/l	0			0	0
Copper	µg/l	5			0	0
Iron (Dis)	µg/l	20			10	50
Iron (Tot)	µg/l			.15		
Lead (Dis)	µg/l	1			0	3
Lead (Tot)	µg/l		20	15		
Manganese	µg/l	7		2	0	0
Mercury	µg/l	0.1	15.4	0.2K	0.1	0
Zinc	µg/l	20			10	10
MBAS	mg/l				0.00	0.00
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	Storet →		USGS-EPA →	
Sample Date		74-03-20	72-09-13	73-01-15	73-06-27	73-09-26
Owner		Holiday Hills	Hatchery Springs →			

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 26/42-11J(S)	→	26/42-12A1(S)		→
Conductivity	umhos/cm	354	358	301	297	291
Residue (Total)	mg/1					
Residue (180°C)	mg/1	198	195	166	165	157
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.27	0.27	0.23	0.22	0.21
pH	--	8.0	7.7	7.7	8.1	8.2
Temperature	°C	11.0	10.3	11.8	10.5	10.0
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	180	170	150	150	140
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.01	0.01	0.02	0.01	0.01
NO_2 -N	mg/1	0.004	0.001	0.000	0.001	0.004
NO_3 -N	mg/1	2.3	2.0	1.3	1.1	0.92
Kjeldahl-N	mg/1	0.04	0.26	0.05	0.15	0.15
PO_4 -P (Total)	mg/1	0.012	0.013	0.003	0.004	0.008
PO_4 -P (Ortho)	mg/1	0.010	0.007	0.002	0.002	0.007
Chloride	mg/1	5.6	5.8	2.3	3.4	2.5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	4	3	1	0	5
Cadmium	µg/1	0	0	1	0	0
Chromium	µg/1	0	0	0	0	0
Copper	µg/1	1	3	1	0	0
Iron (Dis)	µg/1	0	20	30	10	10
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	0	2	1	2	0
Lead (Tot)	µg/1					
Manganese	µg/1	40	36	0	0	0
Mercury	µg/1	0	0	0	0	0
Zinc	µg/1	0	20	30	10	20
MBAS	mg/1	0.02	0.08	0.00	0.00	0.03
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→			→
Sample Date		73-12-17	74-03-19	73-06-29	73-09-26	73-12-17
Owner		Hatchery Springs	→	Spokane Country Club		→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	26/42-12A1(s)	25/45-18R1	→	→	→
Conductivity	umhos/cm	287	150	210	172	180
Residue (Total)	mg/1		92	131	105	120
Residue (180°C)	mg/1	156				
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.21				
pH	--	8.0	7.8	7.1	7.5	7.6
Temperature	°C	9.5	8.9			
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	140	60	88	88	128
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.01				
NO_2 -N	mg/1	0.002				
NO_3 -N	mg/1	1.1				
Kjeldahl-N	mg/1	0.12				
PO_4 -P (Total)	mg/1	0.013				
PO_4 -P (Ortho)	mg/1	0.003				
Chloride	mg/1	2.2	0	1	2	3
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	2				
Cadmium	µg/1	0				
Chromium	µg/1	0				
Copper	µg/1	0				
Iron (Dis)	µg/1	10				
Iron (Tot)	µg/1		0	0	20	140
Lead (Dis)	µg/1	2				
Lead (Tot)	µg/1					
Manganese	µg/1	14	6	18	15	9
Mercury	µg/1	0				
Zinc	µg/1	10				
MBAS	mg/1	0.05				
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	Storet	→	→	→
Sample Date		74-03-19	70-05-14	71-09-14	71-10-13	71-11-17
Owner		Spokane Country club	C.I.D #2A	→	→	→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/45-18R1	→			→
Conductivity	umhos/cm	170	180	172	150	150
Residue (Total)	mg/1	104	118	104	111	136
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.5	7.7	8.2	7.7	7.7
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	100	82	84	84	132
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	6	7	2	0	3
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	0	120	140	140	140
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	0	0	3	6	3
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				→
Sample Date		71-12-14	72-01-17	72-02-16	72-03-28	72-04-19
Owner		C.I.D. #2A →				→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/45-18R1	→			→
Conductivity	umhos/cm	164	159	168	168	180
Residue (Total)	mg/1	98	122	126	100	367
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.8	7.7	7.4	7.4	7.2
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	90	98	112	100	88
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	1	7	10	2	1
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	20	140	680	40	100K
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					10
Manganese	µg/1	3	0	6	6	2K
Mercury	µg/1					4.6
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet	→			→
Sample Date		72-05-10	72-06-19	72-07-24	72-08-14	72-09-14
Owner		C.I.D. #2A	→			→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	26/42-27N1 →				26/43-5L1(S)
Conductivity	umhos/cm	293	290	292	291	393
Residue (Total)	mg/1					
Residue (180°C)	mg/1	157	164	159	162	221
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.21	0.22	0.22	0.22	0.30
pH	---	7.6	8.1	8.3	7.9	7.6
Temperature	°C	11.8	12.0	11.0	10.8	11.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	140	140	140	140	140
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.03	0.01	0.01	0.01	0.000
NO_2 -N	mg/1	0.000	0.006	0.003	0.001	0.000
NO_3 -N	mg/1	1.20	1.10	0.97	1.3	1.3
Kjeldahl-N	mg/1	0.03	0.12	0.03	0.22	0.05
PO_4 -P (Total)	mg/1	0.008	0.022	0.014	0.022	0.006
PO_4 -P (Ortho)	mg/1	0.007	0.001	0.013	0.006	0.002
Chloride	mg/1	4.0	3.5	3.7	4.0	15.0
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	5	7	4	2	10
Cadmium	µg/1	1	0	0	0	1
Chromium	µg/1	0	0	0	0	0
Copper	µg/1	2	0	2	4	0
Iron (Dis)	µg/1	10	20	20	30	40
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	0	3	0	1	0
Lead (Tot)	µg/1					
Manganese	µg/1	0	0	0	43	0
Mercury	µg/1	0.1	0	0	0	0.1
Zinc	µg/1	40	90	130	160	10
MBAS	mg/1	0.00	0.04	0.02	0.00	0.00
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA →				
Sample Date		73-06-29	73-09-26	73-12-17	74-03-19	73-06-29
Owner		B.W. Livergood →				Wandermeva

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 26/43-5L1(S)	→	→	26/43-7B1(S)	→
Conductivity	umhos/cm	387	394	391	305	304
Residue (Total)	mg/1					
Residue (180°C)	mg/1	214	222	217	168	166
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.29	0.30	0.30	0.23	0.23
pH	—	8.0	8.1	7.7	7.6	8.0
Temperature	°C	12.0	11.5	10.8	11.2	11.0
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	170	180	170	150	150
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.01	0.02	0.01	0.02	0.02
NO_2 -N	mg/1	0.002	0.007	0.001	0.001	0.002
NO_3 -N	mg/1	1.1	0.95	1.1	1.3	1.1
Kjeldahl-N	mg/1	0.11	0.09	0.05	0.05	0.15
PO_4 -P (Total)	mg/1	0.005	0.006	0.010	0.004	0.003
PO_4 -P (Ortho)	mg/1	0.004	0.005	0.003	0.001	0.003
Chloride	mg/1	14.0	14.0	14.0	2.3	2.3
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	3	1	2	4	64
Cadmium	µg/1	0	0	0	1	0
Chromium	µg/1	0	0	0	0	0
Copper	µg/1	0	0	2	0	0
Iron (Dis)	µg/1	30	10	90	10	10
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	3	0	2	0	1
Lead (Tot)	µg/1					
Manganese	µg/1	0	0	29	0	0
Mercury	µg/1	0	0	0	0	0.1
Zinc	µg/1	20	0	20	10	10
MBAS	mg/1	0.00	0.05	0.08	0.00	
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA	→	→	→	→
Sample Date		73-09-26	73-12-17	74-03-19	73-06-29	73-09-26
Owner		Wandermere	→	→	Dept. of Game	→

APPENDIX I

WATER QUALITY DATA

PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	26/43-7B1(5) →		26/45-35F1 →		26/45-36N1
Conductivity	umhos/cm	294	311	276	277	296
Residue (Total)	mg/1					
Residue (180°C)	mg/1	155	162	149	151	139
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.21	0.22	0.20	0.21	0.19
pH	---	8.2	8.0	7.6	8.0	7.4
Temperature	°C	10.0	9.6	8.6	8.5	9.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	150	150	140	140	150
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.02	0.01	0.01	0.01	0.09
NO_2 -N	mg/1	0.002	0.005	0.000	0.001	0.001
NO_3 -N	mg/1	0.85	1.1	0.47	0.43	0.62
Kjeldahl-N	mg/1	0.06	0.04	0.05	0.04	0.09
PO_4 -P (Total)	mg/1	0.008	0.007	0.003	0.006	0.014
PO_4 -P (Ortho)	mg/1	0.005	0.003	0.002	0.006	0.001
Chloride	mg/1	2.3	2.4	0.8	1.0	1.3
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	3	2	1	2	0
Cadmium	µg/1	0	0	1	0	3
Chromium	µg/1	0	0	0	0	0
Copper	µg/1	1	6	3	5	70
Iron (Dis)	µg/1	10	10	110	30	2400
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	0	1	0	11	45
Lead (Tot)	µg/1					
Manganese	µg/1	0	36	0	10	30
Mercury	µg/1	0	0.1	0.1	0	0.1
Zinc	µg/1	0	20	30	30	560
MBAS	mg/1	0.02	0.00	0.00	0.04	0.00
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		USGS-EPA →				
Sample Date		73-12-17	74-03-19	73-06-28	73-09-25	73-06-28
Owner		Dept. of Game →		C.I.D. #10A →		G.N. Siverson

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		26/45-36N1	→	26/45-36Q1		→
Conductivity	umhos/cm	301	305	274	274	279
Residue (Total)	mg/1					
Residue (180°C)	mg/1	158	168	148	155	176
Residue, Calculated	mg/1					
Residue Loading	TON/AFT	0.21	0.23	0.20	0.21	0.24
pH	--	7.9	8.2	7.8	7.9	8.0
Temperature	°C	9.0	9.2	11.0	11.0	11.0
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	150	160	140	140	140
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1	0.03	0.06	0.04	0.02	0.01
NO_2 -N	mg/1	0.001	0.006	0.000	0.004	0.002
NO_3 -N	mg/1	0.87	0.77	1.0	1.0	0.94
Kjeldahl-N	mg/1	0.09	0.04	0.05	0.06	0.03
PO_4 -P (Total)	mg/1	0.005	0.023	0.004	0.008	0.009
PO_4 -P (Ortho)	mg/1	0.004	0.006	0.002	0.005	0.009
Chloride	mg/1	1.0	1.2	1.5	1.8	1.6
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1	5	7	4	31	6
Cadmium	µg/1	0		0	0	0
Chromium	µg/1	0	0	0	0	0
Copper	µg/1	29		9	1	4
Iron (Dis)	µg/1	550	1500	50	60	60
Iron (Tot)	µg/1					
Lead (Dis)	µg/1	11		2	4	0
Lead (Tot)	µg/1					
Manganese	µg/1	0	30	0	0	0
Mercury	µg/1	0	0	0	0	0
Zinc	µg/1	250	460	120	120	160
MBAS	mg/1	0.00	0.00	0.00	0.03	0.00
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source						
Sample Date		73-09-26	73-12-18	73-06-27	73-09-26	73-12-18
Owner		G.N. Siverson	→	Borden		→

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number: 26/46-31M1	→	→	→	→
Conductivity	umhos/cm	232	208	232	260	247
Residue (Total)	mg/1	102	165	137	162	133
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	8.4	7.1	7.6	7.8	7.6
Temperature	°C	8.4				
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	100	160	122	162	120
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3	3	3	3	5
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	420	80	20	0	400
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	60	15	9	3	3
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		70-05-14	71-09-14	71-10-13	71-11-16	71-12-14
Owner		C.I.D. # 11A →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Parameter	Units	Well Identification by USGS Number				
		26/46-31M1 →				
Conductivity	umhos/cm	246	254	240	220	240
Residue (Total)	mg/1	215	151	155	177	138
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.5	8.3	7.8	7.8	8.1
Temperature	°C					10.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	196	144	132	160	134
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3	6	0	3	2
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	0	80	180	120	220
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	6	6	0	3	0
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet →				
Sample Date		72-01-17	72-02-16	72-03-28	72-04-19	72-05-12
Owner		C.I.D. #11A →				

APPENDIX I
WATER QUALITY DATA
PRIMARY AQUIFER

Well Identification by USGS Number

Parameter	Units	26/46-31M1				
Conductivity	umhos/cm	224	244	220	240	
Residue (Total)	mg/1	140	150	410	158	
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.6	7.4	7.7	7.2	
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	132	136	372	121	
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1					
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3	3	1	1	
Sulfate	mg/1					
Fluoride	mg/1					
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	60	240	.60	100K	15
Lead (Dis)	µg/1					
Lead (Tot)	µg/1				20	30
Manganese	µg/1	3	6	9	0	2
Mercury	µg/1				8.2	0.2 K
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify)						
Source		Storet				
Sample Date		72-06-19	72-07-24	72-09-14	72-09-14	73-01-15
Owner		C.I.D. #11A				

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number				
		21/44-3C	21/45-30B	22/42-4B	22/45-19D	23/41-12N
Conductivity	umhos/cm	280	232	690	216	256
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	—	7.3	7.6	7.3	7.05	7.56
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	156	106	328	104	88
Alkalinity ($CaCO_3$)	mg/1	146	110	250	96	122
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.52	0.46	14.0	3.60	1.54
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.140	0.010	0.13	0.068	0.075
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	12.0	3.0	33.0	5.0	2.25
Sulfate	mg/1	24.8	16.9	50.4	18.0	0.98
Fluoride	mg/1	0.198	0.29	0.35	0.36	0.37
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	520	100	320	0	860
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1	6	6	6		
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color	---	11	5	5	7	23
Source		DSHS →				
Sample Date		72-01-04	71-04-22	71-12-21	71-01-22	70-07-24
Owner		#1 Waverly Hts	#1 City of Latah	#2 City of Spangle	#1 Fairfield	#3 Cheney

APPENDIX II

WATER QUALITY DATA

BASALT AQUIFER

Parameter	Units	23/41-13D	23/41-13D	23/41-13E	23/41-13C	23/41-13C
		Well Identification by USGS Number				
Conductivity	umhos/cm	263	256	336	284	200
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	8.25	8.03	8.15	7.6	7.3
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	94	88	118	104	72
Alkalinity ($CaCO_3$)	mg/1	124	116	124	122	108
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.97	0.93	1.18	2.14	3.05
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.013	0	0	0.313	0.551
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.5	2.25	8.0	4.0	1.5
Sulfate	mg/1	10.92	8.25	33.25	16.8	5.4
Fluoride	mg/1	0.35	0.36	0.36	0.32	0.21
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	660	280	0	40	240
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		20	15	2	10	8
Source		DSHS →				→
Sample Date		70-07-24	70-07-24	70-07-24	70-10-16	70-10-16
Owner		#1 Cheney	#2 Cheney	#4 Cheney	#1 Eastern W. State College	#2 →

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	23/45-28N	24/40-3N1	24/41-23	25/41-25E	25/41-26H
		Well Identification by USGS Number				
Conductivity	umhos/cm	300	229	240	332	150
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.72	7.95	7.2	7.65	7.35
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	120	80	124	96	64
Alkalinity ($CaCO_3$)	mg/1	154	100	126	53	50
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.2	0.9	5.2	10.3	4.2
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.013	0	0	0.153	0.137
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.0	1.25	6.0	2.5	5.25
Sulfate	mg/1	7.4	9.35	16.8	17.6	23.0
Fluoride	mg/1	0.39	0.36	0.23	0.16	0.146
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	580	300	0	340	240
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		4	15	11	5	55
Source		DSHS →	→	→	→	→
Sample Date		70-12-21	7 -0[illegible] 21	71-08-23	71-08-17	71-08-17
Owner		#2 Rockford	#1 Eastern W. State Hospital	#1 Four Lakes	#3 Airway Heights	#2 Airway Heights

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number				
		25/42-29	22/45-19	23/42-5	24/40-10	24/40-11H
Conductivity	umhos/cm	220	312	240	226	660
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.95	7.35	7.45	7.78	8.1
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	99	116	130	80	104
Alkalinity ($CaCO_3$)	mg/1	104	106	106	108	74
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	1.9	9.63	1.22	1.75	1.8
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.016	0.065	0.052	0.026	0.085
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.25	22.0	3.75	2.0	36.0
Sulfate	mg/1	5.4	36.4	40.8	10.48	68.0
Fluoride	mg/1	0.28	0.24	0.145	0.38	0.14
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	10	0	160	340	280
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		3	12	14	13	8
Source		DSHS →				
Sample Date		70-12-10	70-08-11 70-08-11	70-08-26	70-07-21	73-07-10
Owner		Spokane Int. Airport	Rhamqeist Res in Fairfield	Fish Lake Sars	#2 Eastern W. State Hosp →	#1a

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number: 24/42-12J	24/42-16M	24/42-22	24/43-28L	24/43-28Q
Conductivity	umhos/cm	292	620	212	340	380
Residue (Total)	mg/l					
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	—	7.6	7.6	7.7	7.9	7.4
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	138	274	74	160	158
Alkalinity ($CaCO_3$)	mg/l	142	254	97	168	72
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l	1.05	4.9	0.75	1.09	2.0
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l	0.028	0.235	0.003	0.020	0.029
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	2.5	48.0	1.25	5.0	9.0
Sulfate	mg/l	7.7	58.0	7.7	16.8	22.0
Fluoride	mg/l	0.20	0.182	0.34	0.21	0.31
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	0	200	230	20	160
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l					
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		10	6	8	13	11
Source		DSHS →				
Sample Date		71-07-21	72-06-05 72-09-06	70-06-03	71-06-07	71-06-07
Owner		#1 Hallman? Ranchos	#3 Picnic Pines	Marshall Comm. W.S.	#2 Hangman Valley Golf	#1 →

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	24/44-28N	24/44-33F	25/41-26	25/42-18F	25/42
		Well Identification by USGS Number				
Conductivity	umhos/cm	240	192	360	172	208
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.4	7.6	7.8	7.3	8.0
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	116	128	122	72	112
Alkalinity ($CaCO_3$)	mg/1	138	138	144	56	148
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.029	0.6	11.2	3.4	1.2
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.085	0.261	0.196	0.023	0.029
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3.25	0	9.0	1.0	7.0
Sulfate	mg/1	14.5	9.5	15.8	17.7	13.8
Fluoride	mg/1	0.325	0.28	0.10	0.13	0.38
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	140	620	180	100	40
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		6	10	4	20	2
Source		DSHS				
Sample Date		72-10-10	71-07-29	70-09-?	71-05-06	72-08-30
Owner		Tom Hodges	#1 County Park	#4 Airway Heights	#1 Balmer Gardens	Spokane Int. Airport

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number: 22/43-32L	24/40-3N1 →		24/40-22L1 →	
Conductivity	umhos/cm	359	255	265	284	277
Residue (Total)	mg/1					
Residue (180°C)	mg/1	285	178		197	195
Residue, Calculated	mg/1	266	185		191	201
Residue Loading	TON/AFT					
pH	--	7.3	7.8	7.9	7.9	7.6
Temperature	°C	9.4		14.4	13.3	20.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	118	97	100	118	118
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	12.6	0.00		0.090	0.00
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1	0.140	0.00			
Chloride	mg/1	13.0	3.0		5.5	3.8
Sulfate	mg/1	24.0	11.0		20	21
Fluoride	mg/1	0.3	0.5		0.2	0.3
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	30	200		120	
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	0		5	0
Source		VanD #5	VanD #5 →		VanD #5 →	
Sample Date		61-05-02	59-12-01	60-05-16	57-11-06	58-07-22
Owner		W. Hendrixson	E. State →		U.S. Govt 45C →	

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number: 24/40-22L1 →			24/41-3N →	
Conductivity	umhos/cm	294	296	291	220	220
Residue (Total)	mg/l					
Residue (180°C)	mg/l	204	205	197	163	167
Residue, Calculated	mg/l	206	201	203		
Residue Loading	TON/AFT					
pH	--	8.3	8.2	8.0		7.9
Temperature	°C	15.6		12.2	15.0	16.1
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	117	118	116	90	80
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l	0.00	0.045	0.045	0.023	0.00
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	5.5	5.0	6.2	2.8	2.4
Sulfate	mg/l	21	19	19	11	11
Fluoride	mg/l	0.4	0.30	0.30	0.20	0.40
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l	100	30	70	20	20
Iron (Tot)	µg/l					
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l					
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	5	5		
Source		Van D. + S →			Van D. + S →	
Sample Date		59-09-23	60-09-12	60-11-08	47-02-26	47-08-05
Owner		U.S. Gov't 45C →			U.S. Govt Fairchild #2 →	

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number				
		24/41-3N				
Conductivity	umhos/cm	225	218.	203	215	212
Residue (Total)	mg/1					
Residue (180°C)	mg/1	164	168	155	164	164
Residue, Calculated	mg/1				171	170
Residue Loading	TON/AFT					
pH	--	7.6	7.7	7.6	7.7	7.7
Temperature	°C		15.0	13.9	13.3	15.0
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	89	87	80	88	85
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.00	0.203	0.790	0.068	0.045
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3.8	2.6	2.1	2.2	2.1
Sulfate	mg/1	11	11	12	11	10
Fluoride	mg/1	0.3	0.2	0.2	0.2	0.4
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	40	60	130	50	10
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color					2	5
Source		Van. D. & S				
Sample Date		48-01-01	48-08-11	49-07-19	50-12-06	51-X-X
Owner		U.S. Govt. Fairchild #2				

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Well Identification by USGS Number

Parameter	Units	24/41 – 3N				
Conductivity	umhos/cm	220	183	219	224	219
Residue (Total)	mg/1					
Residue (180°C)	mg/1	166	143	164	166	160
Residue, Calculated	mg/1	167	143	168	170	164
Residue Loading	TON/AFT					
pH	—	7.5	7.5	7.9	7.2	7.7
Temperature	°C	16.1	15.0	16.1		11.1
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	89	68	86	86	86
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.023	1.806	0.090	0.045	0.068
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.1	2.3	2.6	2.8	2.5
Sulfate	mg/1	11	9.7	11	10	11
Fluoride	mg/1	0.3	0.3	0.3	0.3	0.4
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	40	30	80	100	460
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	2	4	5	0
Source		VanD #5	→	→	→	→
Sample Date		53-01-14	53-12-15	54-10-06	55-06-16	56-06-05
Owner		U.S. Govt Fairchild #2	→	→	→	→

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number				
		24/41-3N →				
Conductivity	umhos/cm	215	184.	214	218	208
Residue (Total)	mg/1					
Residue (180°C)	mg/1	155	139	154	164	156
Residue, Calculated	mg/1	158			166	157
Residue Loading	TON/AFT					
pH	---	7.6	7.4	7.6	7.8	7.8
Temperature	°C	12.2	12.2	14.4	20.6	15.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	85	71	85	88	82
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.226	2.100	0.090	0.136	0.519
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	1.8	2.0	2.2	1.8	2.2
Sulfate	mg/1	14	11	11	10	12
Fluoride	mg/1	0.3	0.2	0.3	0.4	0.4
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	120	30	170		290
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		0	0	5	5	0
Source		Van D. # 5 →				
Sample Date		56-10-30	57-07-30	57-11-06	58-07-22	59-09-22
Owner		U.S. Gov't Fairchild #2 →				

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Well Identification by USGS Number

Parameter	Units	24/41-3N	→	24/41-11N1	→	→
Conductivity	umhos/cm	275	262	129	121	136
Residue (Total)	mg/1					
Residue (180°C)	mg/1	168	162	110	110	112
Residue, Calculated	mg/1	173	160		109	112
Residue Loading	TON/AFT					
pH	--	8.0	7.8	7.5	7.1	7.8
Temperature	°C	12.2	15.6	12.8	15.0	15.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	133	125	52	51	52
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	1.016	0.723	1.355	1.400	1.603
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5.2	3.5	1.0	1.2	2.8
Sulfate	mg/1	14	14	5.8	6.3	7.0
Fluoride	mg/1	0.3	0.2	0.2	0.2	0.5
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	280	630	80	30	10
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		0	5	5	0	0
Source		Van D. & S	→	→	→	→
Sample Date		60-11-08	61-10-10	57-11-05	58-07-22	59-09-23
Owner		U.S. Govt. Fairchild #2	→	U.S. Govt N. 11 37C4L	→	→

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number				
		24/41-11N1	24/41-23K1	25/40-14R1	→	→
Conductivity	umhos/cm	135		229	240	235
Residue (Total)	mg/1					
Residue (180°C)	mg/1	107	188	155	167	172
Residue, Calculated	mg/1	105	187		172	164
Residue Loading	TON/AFT					
pH	—	7.9		7.8	7.5	8.3
Temperature	°C	10.0		14.4	20.0	16.1
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	50	135	93	100	98
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	1.400	5.42	0.158	0.226	0.113
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.2	1.7	3.0	5.2	3.8
Sulfate	mg/1	6.6	10	9.6	8.1	8.2
Fluoride	mg/1	0.2	0.1	0.3	0.7	0.6
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	60	120	40		20
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	0	5	0	0
Source		Van. D. & S	USGS unpublished	Van D. & S →		
Sample Date		60-11-08	70-11-10	57-11-06	58-07-22	59-09-23
Owner		U.S. Gov't Well 37C&L	Four Lakes Water Dist	U.S. Govt. 87L →		

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	25/40-14R1	25/40-34NE¼			
Conductivity	umhos/cm	247	283	281	282	288
Residue (Total)	mg/1					
Residue (180°C)	mg/1	165	203	206	205	198
Residue, Calculated	mg/1	174		203	209	206
Residue Loading	TON/AFT					
pH	--	8.0	7.8	7.2	7.7	7.7
Temperature	°C	11.1	10.6	21.1	15.6	12.2
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	97	108	112	111	111
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.090	2.71	2.71	2.94	2.94
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	5.5	5.0	4.5	5.2	6.8
Sulfate	mg/1	7.8	4.5	4.2	5.4	5.0
Fluoride	mg/1	0.4	0.3	0.4	0.8	0.4
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	40	40		0	30
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	5	0	0	5
Source		Van D#5				
Sample Date		60-11-08	57-11-05	58-07-22	59-09-23	60-11-08
Owner		U.S.Gov't 87L	U.S.Govt 87C#2			

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

(15)

Parameter	Units	Well Identification by USGS Number: 25/41-1R1 →			25/41-10G1 →	
Conductivity	umhos/cm	270	283	291	373	334
Residue (Total)	mg/l					
Residue (180°C)	mg/l	188	190	193	257	239
Residue, Calculated	mg/l	191	195	203		244
Residue Loading	TON/AFT					
pH	—	7.2	8.0	7.8	7.9	7.4
Temperature	°C	20.0	16.7	13.9	16.1	18.9
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	124	126	124	160	150
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l	0.0	0.0	0.068	11.97	10.39
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	2.5	3.0	6.2	3.0	3.0
Sulfate	mg/l	6.4	9.3	11	22	20
Fluoride	mg/l	0.3	0.5	0.4	0.1	0.2
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l		560	150	30	
Iron (Tot)	µg/l					
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l					
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		0	0	5	5	0
Source		Van D.# 5 →				
Sample Date		58-07-23	59-09-23	60-11-08	57-11-06	58-07-22
Owner		U.S. Govt 07C#2 →			U.S. Govt 07L →	

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Well Identification by USGS Number

Parameter	Units	25/41-10G1	→	25/41-28	25/41-34	→
Conductivity	umhos/cm	306	291	230	311	330
Residue (Total)	mg/1					
Residue (180°C)	mg/1	219	203	145	219	256
Residue, Calculated	mg/1	223	212	144	224	237
Residue Loading	TON/AFT					
pH	---	8.0	7.8	7.7	7.5	7.4
Temperature	°C	16.1	12.2	13.9	13.3	15.6
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	132	120	109	128	128
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	8.58	7.68	0.339	8.81	11.06
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.2	4.2	2.8	7.8	9.5
Sulfate	mg/1	18	17	10	13	14
Fluoride	mg/1	0.4	0.3	0.3	0.3	0.3
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	0	50	20	180	
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		0	5	2	0	0
Source		Van D. & S	→			→
Sample Date		59-09-23	60-11-8	53-12-16	56-10-30	58-07-23
Owner		U.S. Gov't 07L	→	Fairchild #3	U.S. Gov't	→

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Well Identification by USGS Number

Parameter	Units	25/41-34	→	25/42-25 SW¼	→	25/42-29R1
Conductivity	umhos/cm	302	327	284	305	211
Residue (Total)	mg/1					
Residue (180°C)	mg/1	231	229	173	177	166
Residue, Calculated	mg/1	226	230	177	185	162
Residue Loading	TON/AFT					
pH	—	7.6	8.0	8.2	7.7	7.9
Temperature	°C	13.3	12.2	14.4	10.0	
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	123	130	140	159	91
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	9.03	9.71	1.152	1.264	0.452
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	7.0	9.5	3.5	3.5	1.8
Sulfate	mg/1	13	15	14	16	6.7
Fluoride	mg/1	0.2	0.3	0.1	0.0	0.2
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	130		0	90	40
Iron (Tot)	µg/1		620			
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	5	0	5	3
Source		Van D. & S →				
Sample Date		59-09-22	60-11-08	59-09-22	60-11-08	52-02-14
Owner		U.S. Gov't →		US Gov't →		Spokane Int. Airport

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Well Identification by USGS Number

Parameter	Units	25/42-29R1				
Conductivity	umhos/cm	253	213	211	213	211
Residue (Total)	mg/l					
Residue (180°C)	mg/l	188	155	160	153	157
Residue, Calculated	mg/l	182	163	158	152	152
Residue Loading	TON/AFT					
pH	--	8.0	8.1	7.8	8.1	8.0
Temperature	°C	12.8			11.1	11.7
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	111	88	88	86	88
Alkalinity ($CaCO_3$)	mg/l					
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l	2.71	0.723	0.587	0.948	0.946
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l					
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	4.5	1.6	2.5	1.8	1.8
Sulfate	mg/l	15	6	7.2	6.8	6.5
Fluoride	mg/l	0.1	0.3	0.2	0.3	0.1
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l	80	50	60	0	20
Iron (Tot)	µg/l					
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l					
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		3	2	5	0	0
Source		Van D & S				
Sample Date		52-10-15	53-10-27	55-01-07	5-12-22	56-12-18
Owner		Spokane Int. Airport				

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Parameter	Units	Well Identification by USGS Number: 25/42-29R1 →				
Conductivity	umhos/cm	214	258	220	216	209
Residue (Total)	mg/1					
Residue (180°C)	mg/1	153	195	161	161	158
Residue, Calculated	mg/1		190	164	158	162
Residue Loading	TON/AFT					
pH	--	7.8	7.8	7.8	8.0	8.0
Temperature	°C	5.0	4.4		14.4	10.0
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	91	118	93	88	90
Alkalinity ($CaCO_3$)	mg/1					
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	1.42	2.19	1.31	1.20	1.06
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1					
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.0	3.0	2.2	2.0	2.5
Sulfate	mg/1	6.7	14	7.8	6.2	7.4
Fluoride	mg/1	0.2	0.3	0.4	0.3	0.3
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1	70	30	20	10	0
Iron (Tot)	µg/1					
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	0	0	5	0
Source		Van D & S →				
Sample Date		57-11-06	58-09-26	59-09-29	60-09-21	61-10-03
Owner		Spokane Int Airport →				

APPENDIX II
WATER QUALITY DATA
BASALT AQUIFER

Well Identification by USGS Number

Parameter	Units	25/42-31J1	25/42-27K			
Conductivity	umhos/cm		328			
Residue (Total)	mg/1	121				
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.1	7.0			
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	55	144			
Alkalinity ($CaCO_3$)	mg/1		74			
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	1.49	9.8			
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1		0			
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	1.2	11.0			
Sulfate	mg/1	4.9	50.5			
Fluoride	mg/1	0.2	0.083			
Aluminum	μg/1					
Arsenic	μg/1					
Cadmium	μg/1					
Chromium	μg/1					
Copper	μg/1					
Iron (Dis)	μg/1	80	80			
Iron (Tot)	μg/1					
Lead (Dis)	μg/1					
Lead (Tot)	μg/1					
Manganese	μg/1					
Mercury	μg/1					
Zinc	μg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color			4			
Source		W & M	DSHS			
Sample Date		42-07-29	71-11-09			
Owner		Geiger Field	? Spring School			

APPENDIX III
WATER QUALITY DATA
LITTLE SPOKANE AQUIFER

Well Identification by USGS Number

Parameter	Units	27/43-22M	27/43-32K	27/43-33B	27/43-34H	28/42-02M
Conductivity	umhos/cm	400	440	200	370	180
Residue (Total)	mg/l					
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	--	7.9	7.7	7.0	8.0	7.8
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	188	224	88	206	86
Alkalinity ($CaCO_3$)	mg/l	168	189	96	200	82
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l	11.2	1.82	4.2	0.87	25.8
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l	0.300	0.094	0.094	.104	.173
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	3.0	4.0	5.75	2.5	1.5
Sulfate	mg/l	17.4	23.9	14.4	18.3	8.6
Fluoride	mg/l	0.20	0.22	0.48	0.10	0.108
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	0	80	0	180	0
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l					
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		8	4	0	5	3
Source		DSHS →				
Sample Date		70-08-03	71-08-11	70-09-30	72-10-10	70-10-20
Owner		#9 Riverview Hills	#1 Whitworth	#8 Whitworth	#1 Kellogg	#3 Deer Park

APPENDIX III
WATER QUALITY DATA
LITTLE SPOKANE AQUIFER

Parameter	Units	Well Identification by USGS Number				
		28/42-03H	28/42-03H	28/43-23M	29/42-17D	27/43-10J
Conductivity	umhos/cm	180	184	280	180	410
Residue (Total)	mg/l					
Residue (180°C)	mg/l					
Residue, Calculated	mg/l					
Residue Loading	TON/AFT					
pH	--	7.8	7.7	7.9	7.35	8.3
Temperature	°C					
Dissolved Oxygen	mg/l					
Hardness ($CaCO_3$)	mg/l	92	94	184	88	112
Alkalinity ($CaCO_3$)	mg/l	108	92	120	70	220
NH_3 -N	mg/l					
NO_2 -N	mg/l					
NO_3 -N	mg/l	13.4	13.5	5.08	12.8	1.75
Kjeldahl-N	mg/l					
PO_4 -P (Total)	mg/l	0.111	0.104	0.186	0.147	0.006
PO_4 -P (Ortho)	mg/l					
Chloride	mg/l	.75	1.5	0.5	0	5.9
Sulfate	mg/l	9.0	10.6	42.2	9.7	26.3
Fluoride	mg/l	0.11	0.115	0.09	0.12	0.17
Aluminum	µg/l					
Arsenic	µg/l					
Cadmium	µg/l					
Chromium	µg/l					
Copper	µg/l					
Iron (Dis)	µg/l					
Iron (Tot)	µg/l	60	40	0	0	240
Lead (Dis)	µg/l					
Lead (Tot)	µg/l					
Manganese	µg/l					
Mercury	µg/l					
Zinc	µg/l					
MBAS	mg/l					
Oil & Grease	mg/l					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		5	4	5	3	0
Source		DSHS →				
Sample Date		70-10-	70-10-20	70-08-03	70-10-20	73-06-21
Owner		#1 Deer Park	#2 Deer Park	#10 Chattaroy Hills	#4 Deer Park	#1 Wahoo Add

APPENDIX III
WATER QUALITY DATA
LITTLE SPOKANE AQUIFER

Parameter	Units	27/43-26M	27/43-29M	27/43-34J	27/43-34K	28/42-36A
		Well Identification by USGS Number				
Conductivity	umhos/cm	370	360	420	340	200
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.9	8.3	7.8	7.7	7.0
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	202	196	252	232	82
Alkalinity ($CaCO_3$)	mg/1	196	176	186	170	81
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.038	5.2	3.0	1.68	<.01
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.127	.042	0.036	0	0
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	2.5	1.5	19.0	3.5	1.0
Sulfate	mg/1	26.8	18.3	22.6	20.6	7.3
Fluoride	mg/1	0.124	0.18	0.20	0.143	0.168
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	260	140	200	200	20
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		7	2	5	8	6
Source		DSHS →				
Sample Date		72-10-10	72-06-03	72-10-10	72-10-10	72-08-29
Owner		#1 Colbert Elem. School	E.O Pleeger	Mt Spokane Motel	Lane Park Cafe	Wash State Dragoon Creek

APPENDIX III
WATER QUALITY DATA
LITTLE SPOKANE AQUIFER

Parameter	Units	Well Identification by USGS Number				
		29/43-4				
Conductivity	umhos/cm	752				
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	6.9				
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	88				
Alkalinity ($CaCO_3$)	mg/1	69				
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	1.4				
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.01				
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	1.5				
Sulfate	mg/1	7.2				
Fluoride	mg/1	0.126				
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	180				
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		4				
Source		DSHS				
Sample Date		73-05-09				
Owner		Carmil Estates				

APPENDIX IV
WATER QUALITY DATA
OTHER AQUIFERS

Parameter	Units	25/45-14N	25/45-2301	Newman Lake	26/42-14G	26/42-16
		Well Identification by USGS Number				
Conductivity	umhos/cm	120	124	200	220	294
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.3	7.1	6.4	7.2	7.9
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	88	56	56	120	188
Alkalinity ($CaCO_3$)	mg/1	58	56	42	108	164
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.55	0.92	7.80	2.7	1.43
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0.016	0.062	0.036	0.114	0
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	4.5	8.5	34.0	6.5	6.0
Sulfate	mg/1	18.0	4.9	8.9	7.4	23.7
Fluoride	mg/1	0.06	0.082	0.08	0.18	0.193
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	0	40	170	70	180
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		17	8	5	3	5
Sources		DSHS				
Sample Date		71-04-20	71-04-13	69-04-28	71-09-20	73-04-23
Owner		Liberty Lake	Liberty Lake	Newman Lake		Fairview Additions

APPENDIX IV
WATER QUALITY DATA
OTHER AQUIFERS

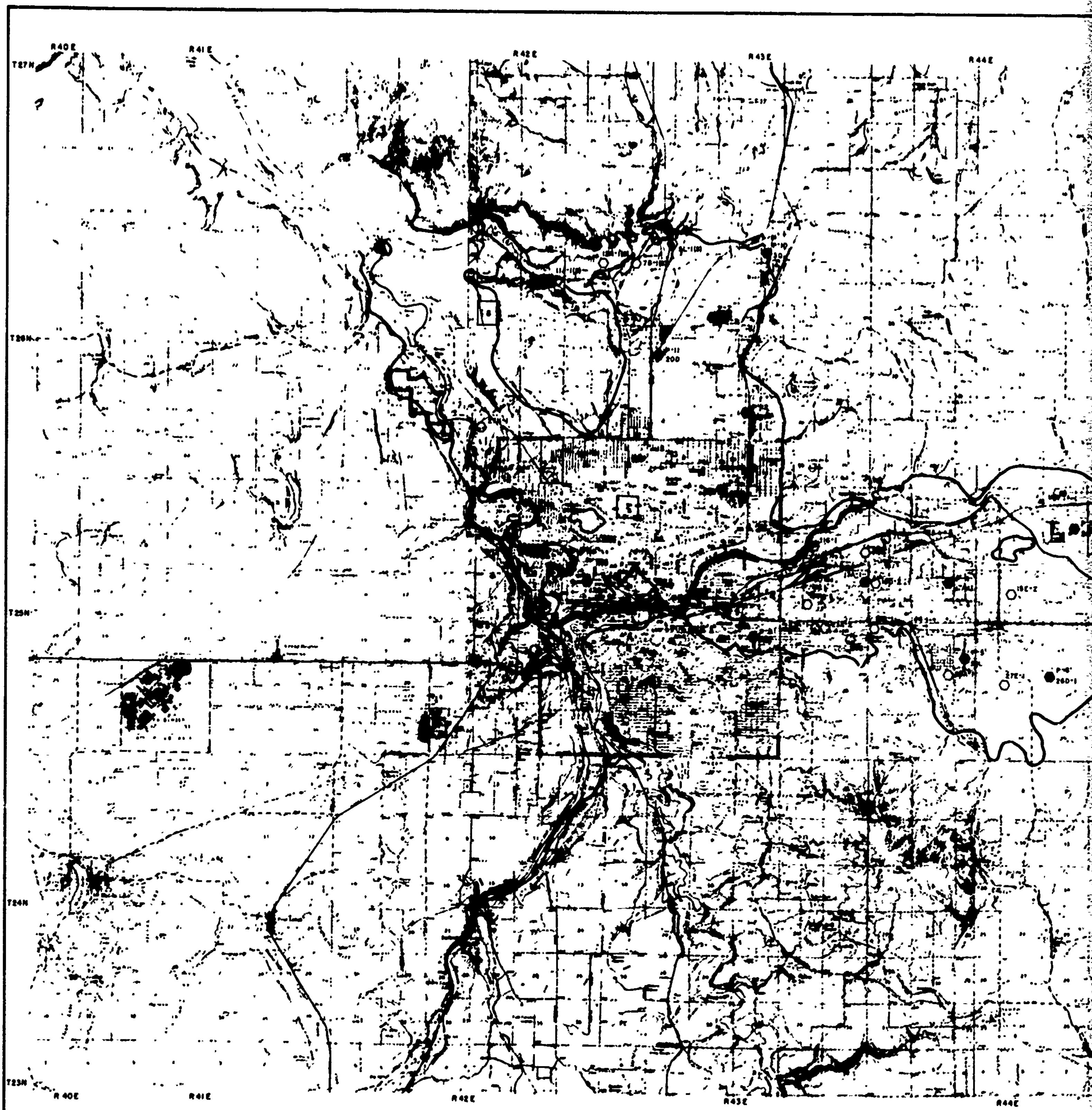
Parameter	Units	Well Identification by USGS Number				
		26/44-29C	26/44-32R	26/44-32Q	26/45-25C	27/41-27G
Conductivity	umhos/cm	528	400	500	200	460
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.1	7.8	7.3	7.2	7.5
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	246	184	256	102	128
Alkalinity ($CaCO_3$)	mg/1	130	178	206	86	184
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	24.8	5.75	11.3	1.04	9.75
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	.068	.052	.082	.072	1.226
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	10.25	3.25	8.5	0	2.25
Sulfate	mg/1	37.1	22.8	25.5	12.7	11.9
Fluoride	mg/1	0.148	0.17	0.07	0.13	0.114
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	460	120	180	140	0
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		7	20	7	13	9
Sources		DSHS →				
Sample Date		71-04-14	71-05-05	71-09-27	71-04-01	70-08-27
Owner		Marvin Bartel	Settlement	Pleasant [illegible]	Moab	Cutler Esenbarth

APPENDIX IV
WATER QUALITY DATA
OTHER AQUIFERS

Parameter	Units	25/45-25F	25/45-25G	26/44-28K	26/45-24C	27/42-21R
		Well Identification by USGS Number				
Conductivity	umhos/cm	220	214	340	246	240
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	---	7.4	7.8	7.4	7.3	7.6
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	88	172	177	144	196
Alkalinity ($CaCO_3$)	mg/1	92	153	102	112	168
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	0.58	<.01	15.9	1.4	0.21
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	0	.098	.127	.059	.104
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	3.5	3.5	8.5	39.5	3.5
Sulfate	mg/1	26.3	16.8	24.8	13.3	21.3
Fluoride	mg/1	1.08	1.07	0.20	0.09	0.11
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	240	10	60	0	60
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		18	4	4	6	4
Sources		DSHS →				
Sample Date		71-06-07	72-09-15	71	71-08-02	71-09-20
Owner		Liberty Lake Park	Liberty Lake Park		Moab	Spokane Lake Park

APPENDIX IV
WATER QUALITY DATA
OTHER AQUIFERS

Parameter	Units	27/45-36	28/45-16G spring	28/45-21A spring	28/45-28L spring	
		Well Identification by USGS Number				
Conductivity	umhos/cm	400	22	18.4	50.8	
Residue (Total)	mg/1					
Residue (180°C)	mg/1					
Residue, Calculated	mg/1					
Residue Loading	TON/AFT					
pH	--	7.9	7.1	7.1	7.3	
Temperature	°C					
Dissolved Oxygen	mg/1					
Hardness ($CaCO_3$)	mg/1	240	68	32	68	
Alkalinity ($CaCO_3$)	mg/1	200	36	34	66	
NH_3 -N	mg/1					
NO_2 -N	mg/1					
NO_3 -N	mg/1	2.8	0.61	0.17	0.32	
Kjeldahl-N	mg/1					
PO_4 -P (Total)	mg/1	.023	0	.010	.033	
PO_4 -P (Ortho)	mg/1					
Chloride	mg/1	8.5	5.5	2.5	5.0	
Sulfate	mg/1	25.0	1.9	14.2	0.3	
Fluoride	mg/1	0.35	0.13	0.30	0.13	
Aluminum	µg/1					
Arsenic	µg/1					
Cadmium	µg/1					
Chromium	µg/1					
Copper	µg/1					
Iron (Dis)	µg/1					
Iron (Tot)	µg/1	80	260	600	380	
Lead (Dis)	µg/1					
Lead (Tot)	µg/1					
Manganese	µg/1					
Mercury	µg/1					
Zinc	µg/1					
MBAS	mg/1					
Oil & Grease	mg/1					
Total Coliform	#100 ml					
Fecal Coliform	#100 ml					
Other (Specify) Color		0	0	5	0	
Sources		DSHS				
Sample Date		72-08-29	71-06-19	73-06-19	73-06-19	
Owner						



MAP SOURCE: USGS 15 MINUTE QUADRANGLE SERIES, CLAYTON WASH 1950, DEER PARK WASH 1949, MT SPOKANE WASH-IDAHO 1950, MEDICAL LAKE WASH 1954, SPOKANE WASH 1950, GREENACRES WASH-IDAHO 1949

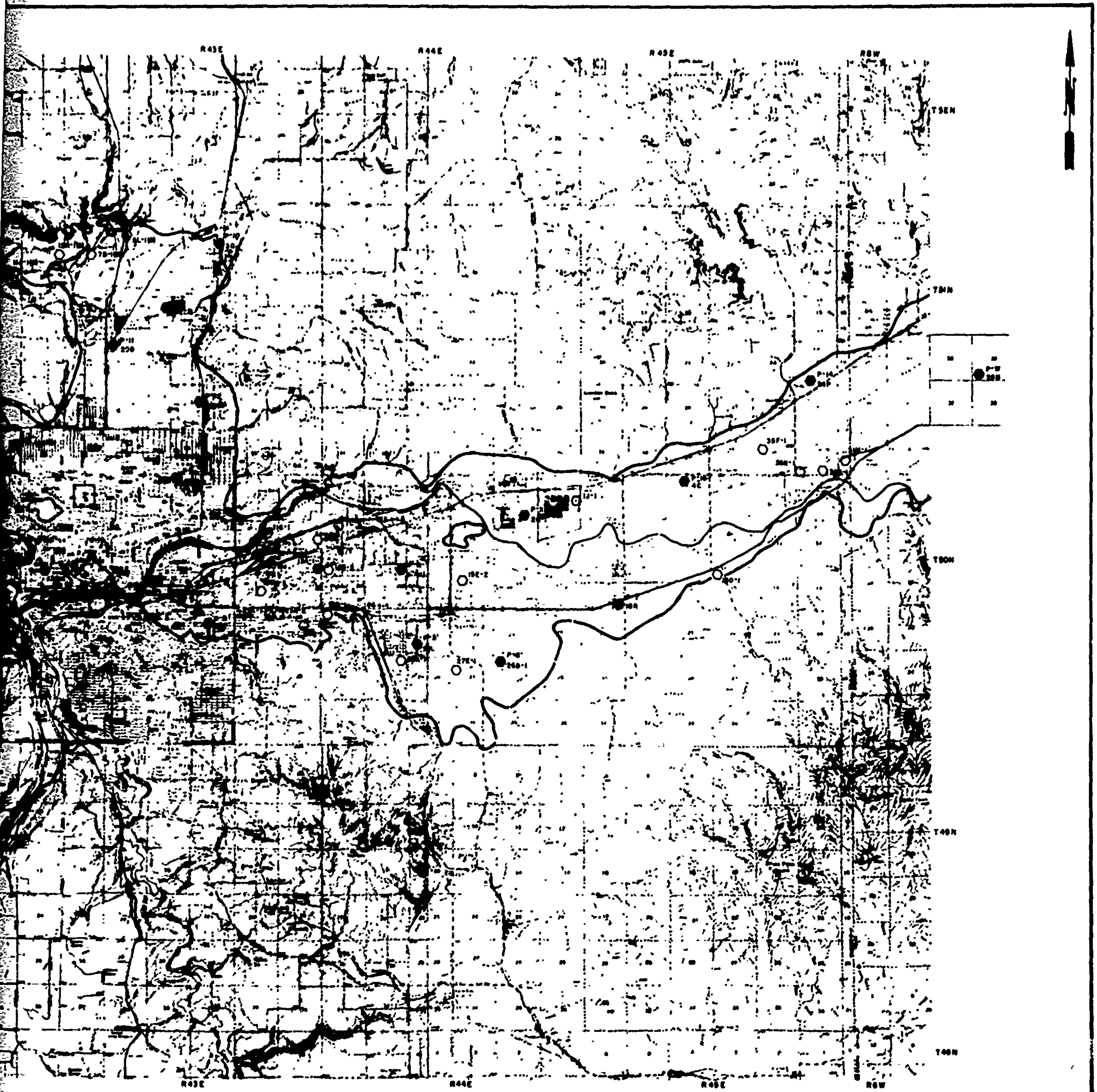
GRAPHIC SCALES

LEGEND

- AVAILABLE WELL SAMPLE
- SUPPLEMENTAL WELL SAMPLE, JUNE 1974
- 2 GAP AREA FOR WHICH THERE IS NO WELL
- AQUIFER BOUNDARY
- 168-4 USGS WELL NUMBER
- B-1 SUPPLEMENTAL SAMPLING WELL NUMBER

REVISIONS

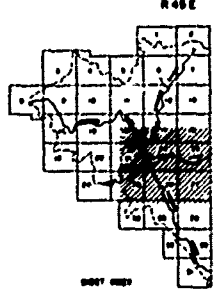
SYMBOL	DESCRIPTION	DATE	BY



...E: USGS 15 MINUTE QUADRANGLE SERIES, CLAYTON WASH. 1950, DEER PARK WASH. 1949, MT SPOKANE WASH-IDAHO 1950, MEDICAL LAKE WASH. 1954, SPOKANE WASH. 1950, GREENACRES WASH-IDAHO 1949.

LEGEND

- ○ AVAILABLE WELL SAMPLE
- ● SUPPLEMENTAL WELL SAMPLE, JUNE 1974
- [2] GAP AREA FOR WHICH THERE IS NO WELL
- —— AQUIFER BOUNDARY
- 16B-4 USGS WELL NUMBER
- R-1 SUPPLEMENTAL SAMPLING WELL NUMBER



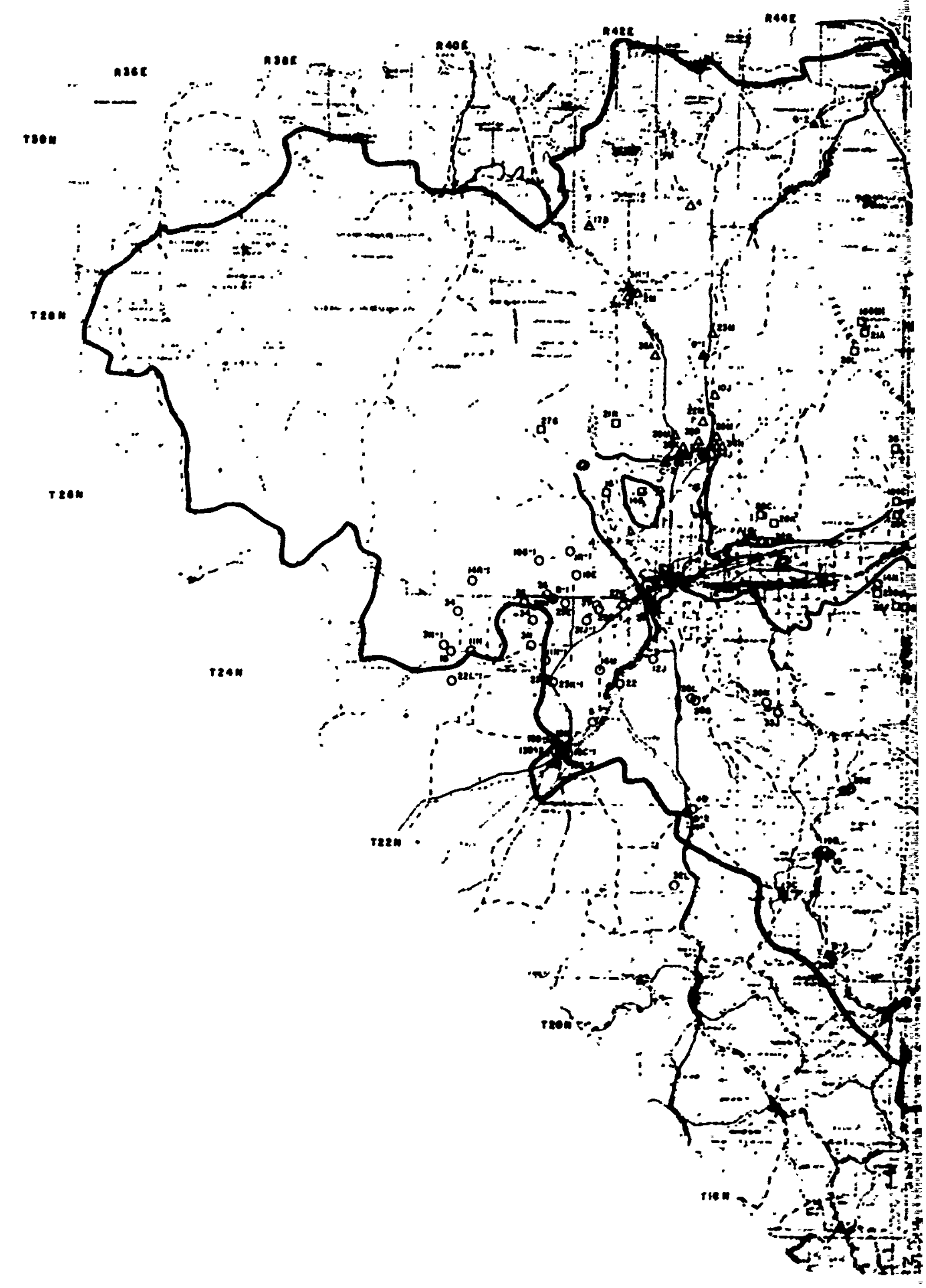
U S ARMY
ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER QUALITY LOCATIONS
PRIMARY AQUIFER

PLATE 405-1

2



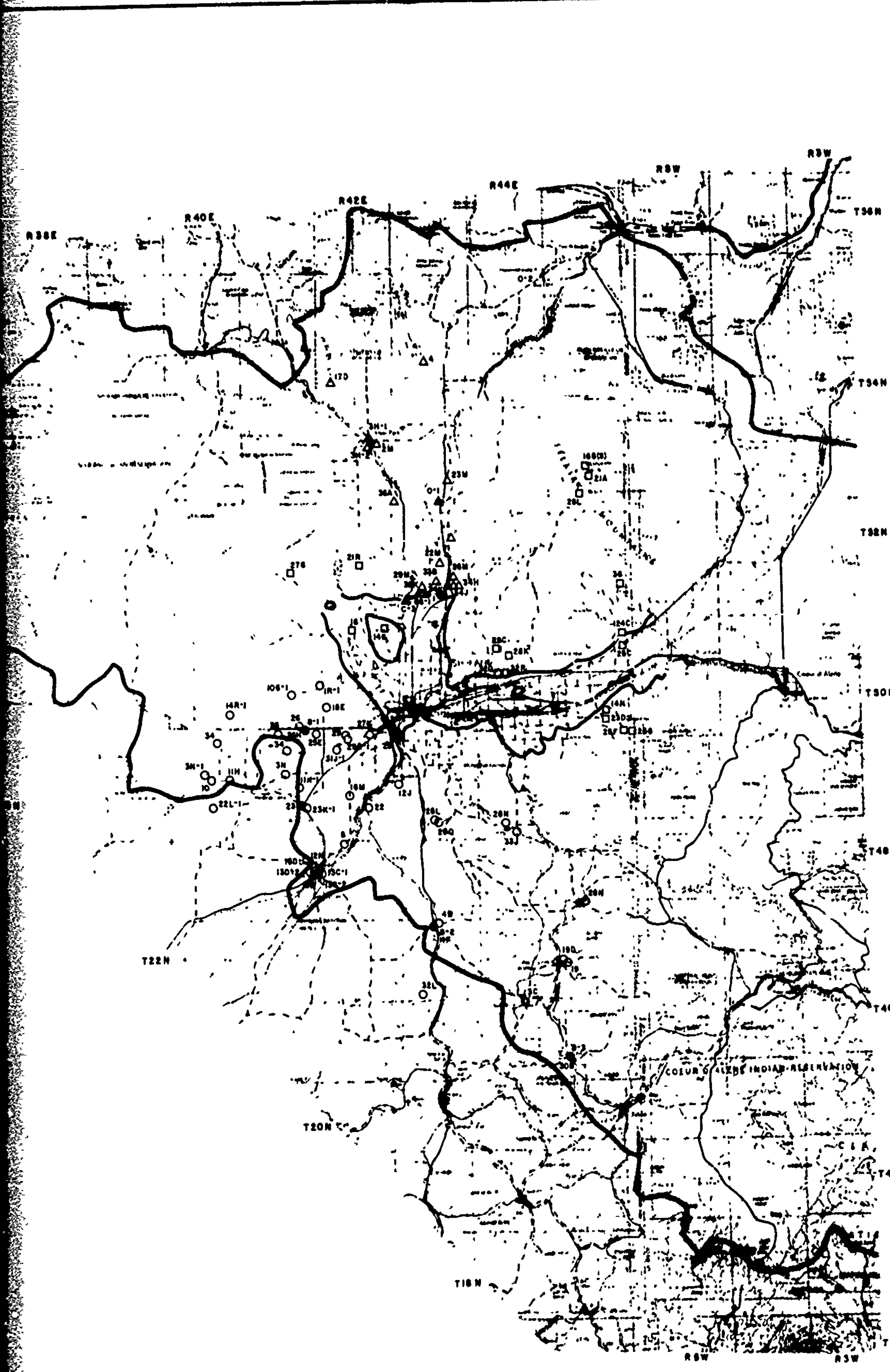
5 0 5 10 15 MILES

10,000 0 10,000 20,000 30,000 70,000 FEET

GRAPHIC SCALES

REVISIONS			
SYMBOL	DESCRIPTION	DATE	BY

MAP SOURCE: PREPARED FROM USGS, UNITED STATES TOPOGRAPHIC SERIES; SANDPOINT 1950, RITZVILLE 1953, SPOKANE 1958, OKANOGAN 1954



LEGEND

- PRIMARY AQUIFER BOUNDARY-FOR DETAILS SEE PLATE 405-1
- ○ AVAILABLE WELL SAMPLE, BASALT AQUIFER
- △ AVAILABLE WELL SAMPLE, LITTLE SPOKANE AQUIFER
- □ AVAILABLE WELL SAMPLE, OTHER AQUIFERS
- ● SUPPLEMENTAL WELL SAMPLE, JUNE 1974, BASALT AQUIFER
- ▲ SUPPLEMENTAL WELL SAMPLE, JUNE 1974, LITTLE SPOKANE AQUIFER
- 16B-4 USGS WELL NUMBER
- B-1 SUPPLEMENTAL SAMPLING WELL NUMBER

WELLS 22/45-19 & 19D; 24/41-23 & 23K-1, 25/41-26 & 26H, 25/42-29 & 29R-1 MIGHT REFER TO ONE WELL EACH, BUT THIS DIFFERENCIATION CANNOT BE PRECISELY DETERMINED FROM THE DATA SOURCES.

MAP SOURCE: PREPARED FROM USGS, UNITED STATES TOPOGRAPHIC SERIES, SANDPOINT 1958, RITZVILLE 1953, SPOKANE 1955, OKANOGAN 1954

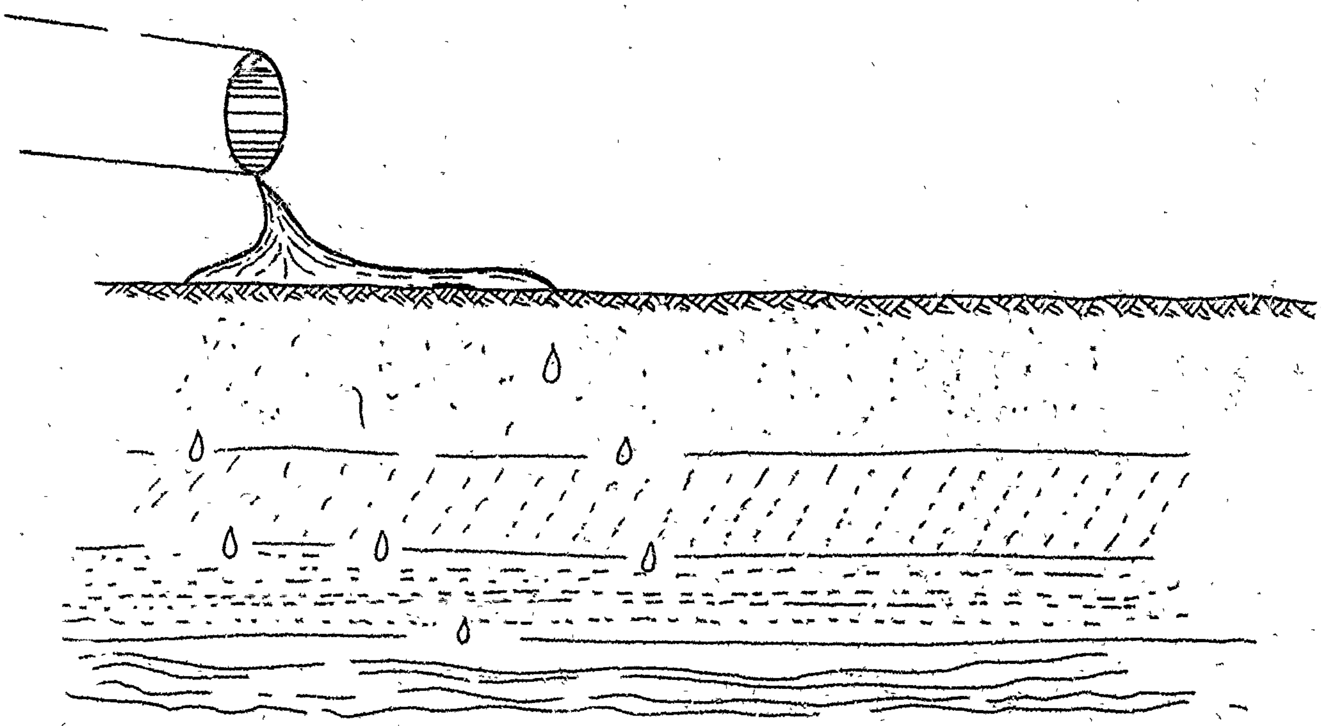
KENNEDY - TUDOR CONSULTING ENGINEERS SEATTLE, WASHINGTON	U S ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION

GROUNDWATER QUALITY LOCATIONS
BASALT AND OTHER AQUIFERS

DACW67-73-C-0006

PLATE 405-2



SECTION 608.1

THE EFFECT OF SURFACE APPLIED WATERS ON GROUNDWATER QUALITY IN SPOKANE VALLEY

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 608.1

THE EFFECT OF APPLIED SURFACE WATERS ON GROUNDWATER QUALITY IN THE SPOKANE VALLEY

18 April 1975

By David K. Todd, Consulting Engineer, Berkeley, California
in cooperation with Kennedy-Tudor

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

INDEX

Subject	Page
Introduction	608.1 - 1
Summary of Conclusions	608.1 - 2
Subsurface Water Movement Under Natural Conditions	608.1 - 4
General	608.1 - 4
Water Balance for Natural Conditions	608.1 - 4
Location	608.1 - 5
Soils	608.1 - 5
Temperature	608.1 - 5
Precipitation	608.1 - 5
Potential Evapotranspiration	608.1 - 5
Actual Evapotranspiration	608.1 - 5
Moisture Deficit	608.1 - 6
Soil Moisture Storage	608.1 - 6
Snow Pack Moisture Storage	608.1 - 6
Percolation to Groundwater	608.1 - 7
Subsurface Water Movement Under Suburban Conditions	608.1 - 7
General	608.1 - 7
Precipitation	608.1 - 7
Septic Tank Effluent	608.1 - 7
Garden Irrigation	608.1 - 8
Water Balance	608.1 - 8
Percolation to Groundwater	608.1 - 9
Estimation of Percolation Under Present-Day Conditions	608.1 - 10
General	608.1 - 10
Groundwater Flow Direction	608.1 - 10
Applied Water	608.1 - 11
Percolation	608.1 - 12
Groundwater Movement	608.1 - 12
Percolation Quality	608.1 - 13
Groundwater Quality	608.1 - 14
Estimation of Percolation for the Year 2020	608.1 - 15
Field Verification of Calculated Quality	608.1 - 16
Independent Field Investigations	608.1 - 17
General	608.1 - 17
Site 1	608.1 - 17

Subject	Page
Site 2	608.1 - 19
Site 3	608.1 - 19
Site 4	608.1 - 19
Summary	608.1 - 20
Recommendations for Further Investigations	608.1 - 20
Tables (See Table Index)	608.1 - c
Figures (See Figure Index)	608.1 - d
List of References	608.1 - 42

TABLE INDEX

Table No.	Title	Page
1	Monthly Climatic, Evapotranspiration, and Soil Moisture Data for Spokane Valley	608.1 - 22
2	Monthly Water Balance Data for Spokane Valley under Generalized Suburban Conditions	608.1 - 23
3	Normal Ranges of Increases in Inorganic Salts in Domestic Sewage (3)	608.1 - 24
4	Summary of Annual Water Balance and Percolation Quality Values for Spokane Valley Planning Units at Present (1975)	608.1 - 25
5	Population Trends in Spokane Valley	608.1 - 26
6	Summary of Annual Water Balance and Percolation Quality Values for Spokane Valley Planning Units at Year 2020	608.1 - 27
7a	Selected Groundwater Quality and Well Data for Spokane Valley, September 1973	608.1 - 28
7b	Selected Groundwater Quality and Well Data for Spokane Valley, September 1971-1972	608.1 - 29

FIGURE INDEX

Figure No.	Title	Page
A	Schematic Diagram of Water Balance for a Surface Soil Layer under Natural and Developed Conditions	608.1 - 30
B	Monthly Mean Air Temperatures for Spokane Valley	608.1 - 31
C	Monthly Mean Precipitation and Potential Evapotranspiration for Spokane Valley	608.1 - 32
D	Monthly Actual Evapotranspiration and Moisture Deficit for Natural Conditions in Spokane Valley	608.1 - 33
E	Monthly Soil and Snow Pack Moisture Storage for Natural Conditions in Spokane Valley	608.1 - 34
F	Disposal of Household Wastewater through a Conventional Septic Tank - Drainfield System	608.1 - 35
G	Monthly Actual Evapotranspiration and Moisture Deficit for Spokane Valley under Generalized Suburban Conditions	608.1 - 36
H	Monthly Soil and Snow Pack Moisture Storage for Spokane Valley under Generalized Suburban Conditions	608.1 - 37
I	Vertical Cross-section Showing Estimated Movement of Groundwater to a Typical Well in Spokane Valley	608.1 - 38
J-1	Variation in Measured Salinity of Groundwater in Spokane Valley as a Function of Distance from the Idaho State Line, Sept. 73	608.1 - 39
J-2	Variation in Measured Salinity of Groundwater in Spokane Valley as a Function of Distance from the Idaho State Line, Sept. 71-72	608.1 - 40
K	Spokane Valley Water Table Contours and Groundwater Flow Line	608.1 - 41

SECTION 608

THE EFFECT OF APPLIED SURFACE WATERS ON GROUNDWATER QUALITY IN THE SPOKANE VALLEY

Introduction

A significant body of groundwater quality data on the Spokane Valley aquifer existed prior to the inception of this study. Concurrent with the study, the USGS-EPA groundwater quality monitoring program added extensively to these data. Additional groundwater quality sampling for this study further supplemented the areal coverage of the USGS-EPA program. Inspection of these accumulated data, unsupported by other considerations, does not permit a conclusive answer to the question: "Are the individual disposal systems (septic tanks and drain fields), which serve approximately 55,000 persons in the Spokane Valley, significantly affecting groundwater quality?"

The investigations of Crosby, et al (6,7,8)* reported a moisture deficit beneath drainfields in summer, suggesting that the septic tank moisture addition was being totally removed by evapotranspiration. On the other hand these same studies reported no significant salt buildup in the soil, which suggests that at some time of the year any salt accumulations are flushed downward. This evidence appears to be contradictory regarding the ultimate fate of the drainfield effluent and its associated dissolved salts.

The known facts about the hydrology of the Spokane Valley aquifer indicate that a flow of approximately 1,000 cubic feet per second (cfs) enters the study area at the Idaho boundary, largely unaffected by man's surface activities up to that point, except for some irrigation in the vicinity of Post Falls. This large flow passes westward under the Spokane Valley, first beneath an area of irrigated agriculture and then under an extensive suburban area serviced entirely by on-site sewage disposal systems. The flow turns northward under the City of Spokane, which is essentially all served by a sewage collection system, and continues northward, again under unsewered suburbs in North Spokane, to discharge into the lower reaches of the Little Spokane River. Throughout the Spokane Valley, the aquifer materials of high permeability extend from the ground surface down to the water table with no known extensive layers of low permeability materials to act as barriers to vertical migration of moisture. There is minor recharge of the aquifer by the Spokane River in the area east of Greenacres. There is a major discharge of some 500 to 600 cfs from the aquifer to the Spokane River along most of the reach from Greenacres to Spokane Falls. The aquifer is extensively penetrated by wells from the Idaho line to the

*See List of References for identification of citations.

Spokane city limits, but there are few wells inside the City and only a moderate number north of the City.

These hydraulic conditions, most significantly the large aquifer flow and the complex interchange with the river, indicate that if septic tank drainfield percolation does reach groundwater its probable effects on chemical quality of the groundwater would be difficult to identify unless supported by such gross indicators as bacterial contamination or detergents. These gross indicators are subject to a high degree of removal by the deep soil layer above the water table, and have not been detected in routine well water examinations. Therefore, it was decided to study analytically the drainfield percolation mechanism to determine if this effluent could be reaching the groundwater; and if so, to estimate the order of magnitude of the changes in groundwater chemical quality that could take place, with emphasis on the total dissolved mineral content, which is known to be largely unaffected by percolation through soil.

The purpose of this portion of the total Water Resources Study is first to determine from calculations of the evapotranspiration mechanism whether moisture is available for percolation under suburban development conditions after evapotranspiration needs are satisfied. If net percolation quantities are determined to exist, a second objective is to estimate the total dissolved solids load which would be carried by this leachate to the water table and its probable effect on the quality of groundwater. A third objective is then to reexamine the existing water quality data and previous related investigations in the light of this knowledge for possible confirmation or to suggest the kind of field investigation needed for confirmation.

It is not the purpose of this portion of the total study to draw conclusions from the above described analyses in either the public health or wastewater management fields. This portion of the study primarily is concerned with the analytical determination of whether the liquid component of septic tank effluent and its accompanying dissolved salts are or will be reaching the water table in the Spokane Valley.

Summary of Conclusions

An analysis of the evapotranspiration mechanism for urban and suburban land use conditions in the Spokane Valley indicates that a significant proportion of the leachate from septic tank drainfields is available for percolation to the water table of the groundwater. The analysis of soil moisture behavior is based on a conservative interpretation of data and a conservative application of soil moisture transport technology. Notwithstanding the conservative approach, the analytical results indicate a net surplus of leachate available for percolation to groundwater.

An evaluation of the physical transport mechanism under pre-

vailing soil and moisture conditions indicates that the dissolved mineral salt content of septic tank effluent is the most reliable indicator for identifying the arrival of leachate at the water table. Since the water supply for the Spokane Valley is drawn from groundwater, the total dissolved solids content of the septic tank effluent is the sum of the salt* content of the water supply and that added by domestic use, which in this case makes the salt content of septic tank effluent more than double that of the water supply. The estimated quantity of leachate reaching the groundwater is sufficient to transport all of the dissolved salts downward with no accumulation in the soil. Therefore, the entire dissolved solids content of the septic tank effluents should be reaching the groundwater, except for minor dissolved constituents such as phosphates, which are known to react with soil particles, or nitrates, which may be partially taken up by plant roots.

This analysis concludes that there is, as a result of the indicated percolation of septic tank effluent and other applied surface waters, an accumulation of these leached flows joining the surface of the native groundwater as it progresses westerly through the valley. The depth and dissolved solids concentration of a layer of leachate accumulated along a groundwater flow line, which for simplification of representation is assumed to be unmixed, is evaluated for both present and forecast year 2020 conditions. Because these leached flows have a significantly higher dissolved solids content than the native groundwaters, their presence should be in evidence as a layer or zone of significantly higher dissolved solids content. This analysis does not address the mechanism of mixing below the water table, because of the lack of depth specific groundwater quality data, but assumes that the depth and degree of mixing are limited and not sufficient to eliminate a distinctive graduation of dissolved solids concentration. The calculated results at the downstream end of the groundwater flow line indicate that the maximum range of solids concentration expected at present is up to 93 milligrams per liter (mg/l) above the mean natural groundwater background of 155 mg/l. The forecast year 2020 maximum incremental concentration is calculated to be 101 mg/l above the natural background.

Confirmation of these concentration differentials from existing water quality data is difficult and uncertain due to lack of information about the penetration of the groundwater by the wells from which samples were drawn. Depending upon depth of penetration of the groundwater and construction details which determine the levels from which water may enter the casing, a well may be pumping native water from beneath the leachate layer, water from the leachate layer itself, or a mixture from both. Despite this limitation, existing water quality data appear to confirm the calculated trend which indicates an increase in total dissolved solids as the groundwater flows westward under the areas served

*Salt is used herein in the general sense to mean any dissolved inorganic compound and is not limited to sodium chloride.

by septic tanks. The available data, however, contain isolated anomolous results which cannot be interpreted for lack of correlative information, and a specific sampling program addressed to meeting the inadequacies of the existing data is recommended. The most critical data need is for depth specific groundwater quality data which suggests that additional groundwater sampling be performed with strict attention given to depth of sample and that simultaneous measurements be made at a number of locations along the groundwater flow path through the valley. Additional depth specific data would provide a firm basis for further verification of analytical results and additional information about the specific chemical composition of the total salt content.

The soil salinity and moisture measurements made in 1967 by the Washington State University investigators appear to verify the analytical result that there should be no salt accumulation above the water table due to the continuous flushing action of the percolate. The reported low soil moisture conditions are likewise compatible with the analytical results which indicate that vertical transport of percolate requires only very small increments of soil moisture above field capacity. (Field capacity is the maximum soil moisture content that can be held by capillar forces and which will not drain under the action of gravity.)

The analytical results of the forecast impact at year 2020 when compared with the present impact, both measured in terms of volume of leachate and dissolved solids concentration, indicate that the present impact on groundwater quality is already a significant proportion of the ultimate level.

<u>Subsurface Water Movement Under Natural Conditions</u>

<u>General</u>. Analysis of groundwater quality within Spokane Valley requires a determination of how and when water, if any, migrates from the land surface to the water table. Before introducing the complexity of septic tanks and suburban development, it is useful to begin with natural conditions--that is, raw land that is neither occupied nor irrigated by man. Subsequent analyses modify these results to reflect suburban conditions.

The approach followed here is to evaluate the monthly water balance of the surface soil layer for natural conditions. Combined for an entire year, these balances indicate whether surplus water is available for percolation to the water table.

<u>Water Balance for Natural Conditions</u>. A water balance for a surface soil layer, such as shown in Figure A, can be determined by evaluating each of the flow components. This is done on a monthly basis for representative conditions in the Spokane Valley. Precipitation is determined from local climatological records. Evapotranspiration can be computed for given climatic, locational, and soil conditions. Surface runoff and percolation are outflows when the moisture holding capacity of the soil is exceeded. For the highly permeable soils in the Spokane Valley, surface runoff is judged to be negligibly

small; therefore, it is assumed that all excess moisture in the soil layer percolates downward.

Location. Soil and climatic conditions representative of Spokane Valley are selected for that portion most subject to septic tank installations; this is assumed to be centered near Opportunity, Washington, at an elevation of 2,000 feet MSL.

Soils. The primary soil in the Spokane Valley is designated a Garrison gravelly loam (GgA) by the Soil Conservation Service. This is an excessively drained soil formed in gravelly glacial outwash material. Its permeability is described as moderate to very rapid. In the top 5 feet it has a water holding capacity (field capacity) of about 5 inches.

Temperature. A 13 year record of air temperature in Spokane (Lat. 47°40'N., Long. 117°25'W.: elev. 1,875 ft.) is available (1) and has a mean value of 48.3°F. This compares with means of 47.8°F. at Spokane Airport and 47.8°F. at Coeur d'Alene. The Spokane (city) record is adopted as most representative of the Valley area. Monthly values are listed in Table 1 and plotted in Figure B.

Precipitation. An isohyetal map prepared in another section of this report shows that the mean annual precipitation in the vicinity of Opportunity is 20 inches. The monthly pattern of precipitation is obtained by correlation with the records of the Spokane (city) weather station, located approximately 9 miles westward. Values are listed in Table 1 and are plotted in Figure C.

Potential Evapotranspiration. Given the above data, mean monthly potential evapotranspiration is computed for the Valley using the method of Thornthwaite (2). Potential evapotranspiration is defined as the maximum amount of water which if available could be removed from the soil by the combined processes of evaporation and transpiration. The values are listed in Table 1 and plotted in Figure C. Note that values range from zero for months with mean temperatures at or below freezing to a maximum in mid-summer. The annual total is 25.51 inches. A hypothetical moisture surplus exists in months when precipitation exceeds potential evapotranspiration (October to March), and a hypothetical moisture deficiency occurs when the reverse is true (April to September), as shown in Figure C.

Actual Evapotranspiration. Because of the moisture deficiency in the Valley during the summer months, the actual evapotranspiration will be something less than the potential. Actual evapotranspiration is defined as the computed amount of water lost considering the limitation of moisture availability. Moisture released to the atmosphere comes from any available precipitation plus soil moisture. For the given climatic and soil conditions of the Valley, the actual evapo-

transpiration can be computed by the Thornthwaite method (2). Monthly values are listed in Table 1 and plotted in Figure D. The annual total is 13.73 inches, which is only 54% of the potential evapotranspiration.

Moisture Deficit. Moisture deficit is a measure of the difference between the potential and actual evapotranspiration. Deficit values are listed in Table 1 and plotted in Figure D. Note that the deficit goes from zero in March to large values in July and August and then drops to zero again in October.

Soil Moisture Storage. Soil moisture exists in three forms which react differently to external forces. Hygroscopic water is that which is so tightly bound to the soil particles that it is not available to plants nor can it be moved by gravity; it can only be removed by heat. Capillary water is bound less tightly to the soil and is available to plant roots but does not move downward under the action of gravity. The sum of the hygroscopic moisture and the capillary water is referred to as the field capacity of the soil. The hygroscopic portion is so small that it can be neglected for the purpose of this study and the entire field capacity is assumed to act as capillary water and be subject to uptake by plants. Moisture above the field capacity is free to move under the force of gravity and would also be available to plant roots within the root zone.

The field capacity of typical Spokane Valley soils is 1 inch of water per foot or approximately 8 percent of the total volume.* The total voids are approximately 30 percent of total volume so that 8/30 of the voids can be occupied by moisture that does not move under the force of gravity.

The amount of moisture stored in the soil will vary seasonally depending upon variations in precipitation and evapotranspiration. Using the Thornthwaite method (2), monthly values of moisture content for the representative Spokane Valley GgA soil (60 inches thick) are computed. Values in inches of water within the soil layer are listed in Table 1 and plotted in Figure E. The maximum moisture holding capacity of 5 inches occurs only in late winter when moisture from snow melt and precipitation greatly exceed evapotranspiration. Note in Figure E that the soil moisture begins to decrease in April, falls rapidly during the spring months, and reaches values of less than one inch for the entire July to October period. Finally, it recovers rapidly during November and December and reaches its maximum again in February.

Snow Pack Moisture Storage. In addition to soil moisture storage, there is a temporary supplemental storage in winter due to the snow pack on the ground surface. Applying the Thornthwaite method (2) to Spokane Valley conditions yields a snow pack moisture storage of 3.15 in January only (see Table 1 and Figure E).

*Source: Soil Survey, Spokane County, Washington, U.S. Dept. of Agriculture, Soil Conservation Service.

Percolation to Groundwater. The above water balance analysis reveals that surplus water over and above potential evapotranspiration is available only during late winter. The snow pack moisture storage of 3.15 inches melts and becomes available at this time, and in addition, there is excess February and March precipitation. Thus, total mean annual available surplus water for a year amounts to 6.01 inches (see Table 1). This percolates downward through the soil layer and to the water table only in late winter. In summer the combination of low precipitation and high evapotranspiration leads to a dessication of the surface layer. Based on this finding, there is a net annual downward transport of water under natural conditions for average and above average years of precipitation. In years of significantly below average precipitation it is possible there would be no net surplus for downward movement.

Subsurface Water Movement Under Suburban Conditions

General. Before proceeding to an analysis of subsurface moisture movement under present and future conditions, involving full recognition of the spatial distribution of development, it is useful to analyze a generalized suburban area with simplifying assumptions. These simplifying assumptions favor maximum evapotranspiration and minimize the potential for creation of surplus soil moisture that would percolate downward. A calculation of this kind should demonstrate whether downward percolation is to be expected under actual suburban conditions.

Determination of a monthly water balance for the same Spokane Valley surface soil layer under suburban conditions requires evaluation of moisture inputs from (a) precipitation, (b) septic tank effluent, and (c) garden irrigation as shown in Figure A for developed conditions.

Precipitation. Representative precipitation for Spokane Valley is defined above and is shown in Table 1.

Septic Tank Effluent. To estimate the effluent from septic tanks in a generalized suburban condition an assumption regarding density of development is required. For extensive tracts of land zoned for residential development, an average lot size of about 14,000 square feet can be adopted. This is equivalent to approximately 3 lots per acre. If the average family consists of 4 persons and the typical effluent production rate is 90 gpcpd*, then the average flow rate per month would be:

(4 persons) (3 lots/Acre) (90 gpcpd) (30 days) =
32,400 gallons/month/Acre **

Converting this to a flow depth over the gross area yields:

---

*gpcpd - gallons per capita per day.
**Note that this is not intended to represent typical average conditions in Spokane Valley but rather the more extreme condition that exists in areas developed as subdivisions.

$$\frac{32{,}400 \text{ gal/mo/A} \times 12 \text{ in/ft}}{7.48 \text{ gal/ft}^3 \times 43{,}560 \text{ ft}^2\text{/A}} = 1.19 \text{ in/mo.}$$

The actual area occupied by the leach lines from three septic tanks on an acre of land would amount to only about 10% of the gross area. Normally such effluent would tend to be distributed slightly laterally by capillary action but mostly downward due to gravity drainage, as indicated in Figure F. The lateral flow component can become significant where the sub-soil layers are highly stratified and where impermeable layers tend to perch and to spread the effluent. In Spokane Valley there appears to be little physical evidence which shows that either of these situations occur; however, vertical permeabilities are undoubtedly lower than horizontal ones.

If septic tank effluent moves essentially downward, it follows that the volume subject to evapotranspiration loss will be minimal because the area of excessively moistened soil will be minimal. On the other hand the opposite extreme would be to assume a lateral spreading of the effluent over the entire area. Although physically highly improbable, this assumption can be useful because it represents the situation tending to maximize the effect of evapotranspiration. Note that this assumption also makes no deduction for the areas covered by streets and houses, which, in reality, are not capable of contributing to evapotranspiration loss. Thus, two assumptions are made, both highly favorable to evapotranspiration and unfavorable to leaving excess moisture available for percolation. With these assumptions, the above computation giving a uniform effluent rate of 1.19 in/mo. can be adopted; this totals 14.28 inches per year. The sum of precipitation plus septic effluent expressed in inches per month over the gross generalized suburban area is listed in Table 2; this amounts to a total annual moisture input of 34.28.

Garden Irrigation. Irrigation of gardens and lawns is another moisture source in a suburban area. This will occur during the growing season and will be at a maximum during the driest and hottest months (July and August) when the moisture deficit is greatest.

Again a simplifying assumption can be made favoring evapotranspiration loss of the septic tank effluent by neglecting garden irrigation which would supplement the effluent in supplying a part of the total evapotranspiration demand. It should be noted that Spokane Valley garden irrigation use is known to be very high from water use records.

Water Balance. Values of temperature, precipitation, and potential evapotranspiration are identical to those shown in Figures B and C in Table 1.

Actual evapotranspiration under generalized suburban conditions

will differ from that of natural conditions because of the increased moisture available from septic tank effluent. Monthly values of actual evapotranspiration computed by the Thornthwaite method are listed in Table 2 and plotted in Figure G. The annual total is 20.35 inches, which is 80% of the potential evapotranspiration.

Moisture deficit, which is the difference between the potential and actual evapotranspiration, is listed in Table 2 and plotted in Figure G. Note that the annual moisture deficit has decreased to less than half of that found under natural conditions, and most of this now occurs in July and August.

Soil moisture storage values within the 60-inch thick GgA soil layer are listed in Table 2 and plotted in Figure H. Under suburban conditions the maximum moisture holding capacity of 5 inches occurs from November to April; minimum values occur only in the late summer months of August and September. A 60-inch layer is selected as typical of the depth of influence of the average non-orchard crop as suggested by Thornthwiate[2].

Snow pack moisture storage is listed in Table 2 and shown in Figure H. According to the Thornthwaite method, this amounts to the total January precipitation.

Percolation to Groundwater. The above water balance indicates that surplus water over and above potential evapotranspiration is available from November through April (see Table 2). The total annual surplus water is 14.22 inches; this is more than double that determined for natural conditions (see Table 1) and is 41% of the total precipitation plus septic tank effluent. Thus, a significant net downward transport of water and associated dissolved solids could occur under generalized suburban development conditions.

Having found that water is available for percolation, it is useful to determine how much moisture in excess of field capacity would be required to account for continuing vertical transport of the surplus moisture under steady state flow condition. For this calculation, a conservative assumption would consider a minimum area and a maximum amount of moisture. Therefore, a calculation is made to determine the steady state moisture to transport the entire septic tank effluent, undiminished by evapotranspiration through an area limited to the actual size of the drainfield. The typical drainfield required by County regulations for a three-bedroom home is approximately 1,800 square feet in area and would be receiving water at the rate of 0.32 inch per day, say 0.50 inch per day. Vertical unsaturated flow at the rate of 0.50 inch per day, or 0.31 gallons per square foot per day, will take place under steady state conditions at a soil moisture of 9.0 percent by volume or 8 percent above the field capacity level of 8.3 percent by volume. This calculation is made on the assumption that the vertical

permeability is only one tenth of the estimated horizontal permeability of the Spokane Valley aquifer material, again a conservative assumption.

What this result indicates is that the observed soil moisture content above the water table should not deviate materially from that of field capacity because only a very small increment is all that is required to sustain percolation rates that could account for transport of all surplus moisture. Therefore, even during the percolation season, soil moistures at depth should remain close to field capacity.

Estimation of Percolation Under Present-Day Conditions

General. The previously described water balance methodology can be applied to present day specific development patterns in the Spokane Valley. Quantities of percolation to the water table from precipitation, septic tank effluent, lawn irrigation, and agricultural irrigation can thus be calculated. Knowing this downward flow rate, the effect on groundwater quality can then be estimated by use of an appropriate quality index parameter.

Dissolved inorganic salts are added to water by domestic use. The laboratory test for dissolved inorganic salts is identified as "total dissolved solids" (TDS). A very large percentage of the materials identified by the TDS test pass undiminished through typical treatment plants including septic tanks and through soil. Only phosphates and certain heavy metals are removed by attachment to or reaction with soil particles. Phosphates usually represent less than fifteen percent of TDS and heavy metals, when present, are a fraction of one percent.

The observed TDS concentration in the City of Spokane wastewater effluent is of the order 440 mg/l. The City water supply which is from Spokane Valley groundwater has an average TDS content of approximately 170 mg/l. This indicates an incremental TDS addition of 270 mg/l. Normal ranges of increases in various salts and TDS due to domestic use are shown in Table 3. Note that the City experience falls within the normal range.

Since the Spokane Valley suburbs have the same water supply, a similar relationship would be expected between the TDS of Spokane Valley wastewater and the TDS of its supply. Thus, septic tank leachate at depth should have a TDS concentration more than double that of the natural groundwater. Therefore, total dissolved solids is selected as an appropriate identifier of the moisture from septic tank effluent as it moves downward to the water table. Since the City experiences some dilution by significant infiltration flows, a value of 300 mg/l is selected as the domestic TDS increment in Spokane Valley use for computational purposes.

Groundwater Flow Direction. It is expected that the largest change in quality of groundwater will occur at the western end of Spokane Valley because of the general east-to-west flow of groundwater. The western boundary of septic tank installations coincides with the

western limit of Planning Unit SV-3 and with the eastern city limit of Spokane. Refer to Figure K. Therefore, groundwater quality in terms of TDS is computed for a hypothetical well located at T25N,R43E,14E1* as an index of the impact of septic tank percolation.

Percolation reaching the groundwater at this location must come from along the flow line of groundwater upstream within Spokane Valley and extending to the Idaho State Line. The required flow line is traced as a dashed line on the water table contour map in Figure K. The water table contours are developed from the following data sources:

(1) Well water levels from Appendix I of Task Report Section 303.

(2) USGS Water-Supply Paper 889-B.

(3) Aerial photographs of May 1, 1973.

(4) Consolidated Irrigation District monthly well water levels.

(5) Rating curves of Spokane River gaging stations.

(6) Bed profile of Spokane River.

All water levels are corrected to a September datum to eliminate seasonal variations.

The flow line above well T25N,R43E,14E1 meanders up the southern half of Spokane Valley. It crosses to the north side of Spokane River at RM 91.6, crosses back to the south side at RM 94.1, and follows close to the river up to the Idaho State Line. The total flow length is 79,800 feet; the distance within each Planning Unit intersected is listed in Table 4.

Applied Water. Mean annual precipitation for each Planning Unit in Spokane Valley is estimated, taking into account the increasing precipitation east of the City of Spokane. Values are listed in Table 4.

Septic tank effluent is computed from estimates of domestic sewage for each Planning Unit for present-day conditions. Annual values in inches mean depth over the area of each Planning Unit are listed in Table 4.

---

*USGS well identification system: Township 25 North, Range 43 East, Southwest quarter of the northwest quarter of Section 14.

Lawn irrigation* is computed as the difference between water demand and domestic sewage. Estimates in inches mean depth for each Planning Unit for 1975 conditions are shown in Table 4.

Agricultural irrigation is computed from estimates of irrigated acreage for each Planning Unit. It is assumed that 3.0 feet of water are applied annually to all irrigated areas. Annual values in inches mean depth over the area of each Planning Unit are listed in Table 4.

Total applied water is the sum of precipitation, septic tank effluent, lawn irrigation, and agricultural irrigation. Values for each Planning Unit appear in Table 4. The largest quantities of applied water occur in the more heavily developed western portions of the Spokane Valley (Planning Units SV-3 and SV-5). Also, the relatively small contributions of septic tank effluent to the total applied water should be noted: 12 percent in Planning Unit SV-3, about 2 percent in Planning Units SV-5 and SV-6, and less than 1 percent in Planning Units SV-7 and SV-8.

Percolation. By application of the Thornthwaite water balance method (2) on a monthly basis, the percolation to groundwater for each Planning Unit is obtained. Potential evapotranspiration rates are reduced for estimated current impervious areas. The following values are used:

Planning Unit	Impervious Area, %
SV-3	13.0
SV-5	2.6
SV-6	2.6
SV-7	0.5
SV-8	1.0

The resulting annual values of percolation are listed in Table 4.

In order to compute the quantity and quality of the percolate from the sum of contributions along the flow line, expressed in inches depth per year, it is first necessary to estimate the flow velocity of the groundwater with which the percolate is assumed to move.

Groundwater Movement

A representative groundwater velocity can be computed using Darcy's law:

$$v_a = \frac{Ki}{\alpha}$$

*Lawn irrigation is defined as non-commercial irrigation and for Spokane Valley includes many private pastures and other extensive areas.

where v_a is the average actual (tracer) velocity, K is permeability, i is the water table gradient, and α is porosity. Based upon given geologic data for Spokane Valley, permeability can be estimated at 75,000 gpd/ft^2, i = 10 ft/mi, and α is 0.30. Substituting these values in the above equation yields 63 ft/day.

Applying this calculated groundwater flow rate, the total depth of water percolating within each Planning Unit along the flow line is computed. Values are shown in Table 4. A sample calculation for Planning Unit SV-3 is

$$\frac{37{,}500 \text{ ft.} \times 11.11 \text{ in/yr.}}{63 \text{ ft/day} \times 365 \text{ day/yr.}} = 18.1 \text{ inches}$$

This states that the percolation from SV-3 arriving at the surface of the groundwater at a rate of 11.11 inches per year and traveling with the groundwater at a rate of 63 feet per day will have an accumulated depth of 18.1 inches at the downstream end of 37,500 feet of exposure. The values shown in Table 4 for flow line percolation for each unit have the same interpretation. Since each exposure is successive, the indicated depths of flow line percolation are cumulative so that the percolated waters have a depth of 34.1 inches at the downstream end of the flow line at the hypothetical well T25N,R43E,14E1. Note that this depth is the net water quantity and not the vertical space that this volume would occupy when filling the void spaces of the aquifer.

Percolation Quality. To determine the TDS concentration of the percolating water for 1975 conditions, the following TDS values are assumed for the various sources:

Percolation Source	Salinity, TDS, mg/l
Precipitation	10
Septic Tanks	455
Lawn Irrigation	155
Agric. Irrigation	155

The above values are based on an average measured salinity of 155 mg/l for groundwater entering the Spokane Valley near the Idaho State Line. Assuming that salt does not accumulate within the zone of aeration above the water table because of the net downward movement of water, the salinity of the percolation can be computed on a mass balance basis. Values for each Planning Unit are listed in Table 4. A sample calculation for Planning Unit SV-3 follows:

$$\frac{19.50(10)+3.95(455)+8.05(155)+0.72(155)}{11.11} = 302 \text{ mg/l TDS}$$

With the quantities and qualities of percolation given, the

mean weighted concentration of percolation, Cpm, at the end of the flow line can be computed using an equation of the form

$$Cpm = \frac{\sum Qp \times Cp}{\sum Qp}$$

where Qp is percolation depth for one Planning Unit and Cp is the TDS of percolation for the Planning Unit. Inserting values from Table 4, the mean salinity becomes 248 mg/l TDS.

This result indicates that the 34.1 inches of accumulated depth of percolated waters at the downstream end of the flow line, if mixed among themselves but unmixed with the underlying groundwater body, would have a mean TDS of 248 mg/l.

Groundwater Quality. Having determined the quantity and quality of the percolate which is reaching the surface of the groundwater, it is necessary to assume how the percolate mixes with the natural groundwater before an evaluation can be made of the impact upon water withdrawn by wells. Undoubtedly some mixing of the percolate and the groundwater occurs, but due to the nature of flow in a porous medium, it is probable that the majority of the percolate remains unmixed in a layer at the top of the groundwater body.

The implication of a substantially unmixed layer of percolate traveling on the surface of the native groundwater body is that wells with varying depths of penetration and levels of openings will yield waters of varying quality. A well penetrating deep into the native body and without casing perforations into the percolate layer could, if no mixing were induced in the aquifer by a very high pumping rate, yield water having a quality equal to that of the native water. On the other hand, a well which penetrates only the percolate layer could produce water with a quality of the undiluted percolate. In terms of the TDS concentration, the concentration could range from 155 to 248 mg/l. Wells which penetrate and have openings into both layers would be expected to have qualities intermediate between these extremes.

The following calculation is made to illustrate the quality in terms of TDS which could appear from a well which penetrates and withdraws water from both the percolate and native water layers. The 34.1 inches of accumulated percolate would occupy a layer 9.5 feet in the typical aquifer materials with 30 percent voids.

A hypothetical well at T25N,R43E,14E1 in the western portion of the Spokane Valley is assumed to penetrate 20 feet below the water table, as shown on Figure I. It is further assumed that water is drawn into the well casing in proportion to the length exposed to each layer. The top 9.5 feet of casing would then be exposed to waters of 248 mg/l TDS while the lower 10.5 feet would be exposed to waters of

155 mg/1 TDS. Mixing these two waters within the well yields pumped groundwater having a concentration as follows:

$$\frac{9.5(248) + 10.5(155)}{20.0} = 199 \text{ mg/l TDS}$$

Large diameter open bottom dug wells which do not penetrate deeply would induce similar mixed qualities by turbulent mixing caused by high pumping rates.

Estimation of Percolation for the Year 2020

In order to evaluate trends in groundwater quality for the Spokane Valley, estimates of percolation are made for the year 2020. Calculations are based on projections of population, water use, domestic sewage production, lawn irrigation, and agricultural irrigation for each contributing Planning Unit in the Valley. Comparative population figures are shown in Table 5.

These data show that the population along the flow line assumed for demonstration purposes will increase by 54 percent over the 1975 level. Furthermore, most of the population growth will be concentrated in Planning Unit SV-3, which, in 1975, was already the primary source of septic tank effluent (see Table 4).

Using the projections described above and the following estimates of impervious areas for the year 2020, calculations of the annual water balance and percolation quality values are made for the year 2020.

Planning Unit	Impervious Area for Year 2020, %
SV-3	18
SV-5	4
SV-6	4
SV-7	1
SV-8	2

The year 2020 results are summarized in Table 6 for each Planning Unit. The format of Table 6 is identical to that of Table 4 so changes in any of the variables between 1975 and 2020 can readily be seen. A key assumption in the 2020 analysis is that all sewage continues to be disposed of by means of septic tanks; introduction of a sewerage system in part or all of the Valley would affect quantities of septic tank effluent and, consequently, groundwater quality.

Comparing 2020 conditions in Table 6 with 1975 conditions in Table 4, the following points can be noted:

(1) Septic tank effluent increases in all areas and Planning Unit SV-3 continues as the predominant contributor.
(2) Lawn irrigation increases moderately in all areas except Planning Unit SV-5.
(3) Agricultural irrigation decreases substantially in all Planning Units.
(4) Total applied water remains essentially unchanged except for a small increase in Planning Unit SV-3.
(5) Percolation increases moderately in Planning Unit SV-3 but changes insignificantly in other areas.
(6) TDS of percolation remains remarkably constant in all areas.

The mean salinity and accumulated volume of the percolate at the end of the flow line will be 256 mg/l TDS and 41.0 inches, respectively, in 2020; this compares with 248 mg/l and 34.1 inches, respectively, for 1975. Similarly, the salt concentration of mixed waters pumped from a hypothetical well penetrating 20 feet below the water table at the western portion of the Spokane Valley in 2020 will be 213 mg/l TDS; the comparable 1975 value is 199 mg/l.

Based on a native groundwater quality of 155 mg/l TDS, the present "hypothetical well" quality at 199 mg/l represents an increase of 28 percent. Similarly, the forecast "hypothetical well" quality in year 2020 at 213 mg/l represents an increase over native condition of 37 percent. These comparisons suggest that groundwater quality in Spokane Valley will change relatively slowly during the next 45 years (1975 to 2020) and that the present day impact of septic tank effluent is a significant proportion of the anticipated future impact. Thus, with a future population increase of 54 percent in Spokane Valley, there will be an estimated increase of 32 percent in well water salinity based on the background level of 155 mg/l in the native groundwater.

Field Verification of Calculated Quality

The foregoing calculations indicate that a substantial amount of percolation from septic tank effluent and other sources should be reaching the surface of the native groundwater and that there should be evidence of this percolate in the form of increased total dissolved solids above that of the native groundwater. The apparent groundwater quality should vary with distance westward from the Idaho State Line and with depth of well penetration below the water table. The scarcity of water quality data, and particularly those associated with well penetration, makes verification of the analytical results difficult.

There are two sources of recent and synoptic data for water quality expressed as TDS. One source is the USGS-EPA program for the period June 1973 to March 1974. For comparative purposes and correlation with the water table contours developed for September, the

sampling of September 1973 is selected. Table 7A lists the wells, the penetration below the September water table, the TDS (Residue 180°C), and the distance west from the Idaho State Line. The other source is the Spokane County Health District survey covering the period September 1971 through September 1972. The mean TDS for the two September samplings is selected for analysis. The quality data, well penetrations and distance from the State Line are listed in Table 7B. Well locations from both sources are shown on Figure K.

The data from Tables 7A and 7B are plotted in Figure J1 and J2 respectively. Note that in both cases, a trend of increasing TDS with distance westward is apparent. This is in basic agreement with the foregoing analytical results. A total of four points from Figure J-1 and one point from Figure J-2 suggest a groundwater TDS of approximately 155 mg/l near the Idaho State Line. Two points from Figure J-2 near the State Line have very low TDS values, approaching that of Spokane River water. There is no apparent explanation for these anomalous values other than extremely deep penetration below the water table. In the area between 7 miles west of the State Line to the City limits (approximately 14.3 miles west of the State Line) there are four points from Figure J-1 and eight points from Figure J-2 that strongly support the trend of increasing TDS, suggesting a mean value of 215 mg/l at the City limit. In Figure J-1 there are two wells in the western area with moderate penetrations of the aquifer that do not follow the trend but are substantially at State Line TDS values. Again, there is no apparent explanation for these anomalous salinities.

The well penetration data listed in Table 7-A and 7-B are plotted beside the well points in Figures J-1 and J-2. Except for a tendency for wells with low penetrations to lie above the trend line and those with high penetrations to lie below the line, no verification of the effect of well depth can be obtained from these limited field data.

Independent Field Investigations

General. A group of investigators at Washington State University studied moisture and pollutant movement at selected sites in Spokane Valley during the summer of 1967. Their findings have been published (6,7,8) and are of interest because they provide independent evidence generally supporting the previously described analytic studies. The following paragraphs briefly summarize the field investigations and then interpret their results in terms of the analytic work.

Site 1. This site (T25N,R44E,20J) was a nursing home and was selected as an example of extreme loading of pollutants in the Valley. Six test holes were drilled in the main sanitary drainfield and three in a separate laundry drainfield; in addition, two test holes for control were drilled nearby. Hole depths ranged from 41 to 66 feet, while the water table was at a depth of 125 feet. Soil samples were collected at 5 to 10 foot intervals and were analyzed for total coliforms, fecal coliforms, enterococci, moisture, chloride, nitrate, detergents, and particle size distribution.

The sample results indicated that bacteria were rapidly

removed in the upper soil layers and that low and relatively uniform values of chloride, nitrate, and detergents were present. Moisture contents were also generally low.

Of particular interest to this study are the salinity measurements reported under the sanitary drain field. In all test holes the chloride ion concentrations found below the top ten feet, that is below the zone of high moisture, are consistently low, never exceeding 10 µg/g* of soil, with most being less than 5 µg/g. The fact that the highest concentrations are associated with the highest moisture contents indicates that salts are in the dissolved form rather than as precipitated deposits. The low salt concentrations must result because they are being constantly flushed out rather than being left behind by evapotranspiration.

The following calculations are made to demonstrate these interpretations:

(1) A typical value for the per capita chloride increment to sanitary sewage is 0.035 pounds per day. For the 100 occupants of the nursing home this totals 3.5 pounds per day or 1,278 pounds per year. If this quantity of chloride for one year were held by evapotranspiration in a soil prism 100 feet square, centered on the 40 foot square drainfield, and extending to the depth of the borings at 60 feet, it would appear as a concentration of approximately 17.5 µg/g. In 1967 the drain field had been operating at least 10 years, by which time total chloride would have a concentration of 175 µg/g. These values are 10 and 100 times, respectively, more than the measured values.

It is of interest to calculate the zone of soil influence that would have to be involved to lower the mean concentration of 10 years deposition to 2.5 µg/g, which is the order of magnitude of the mean observed chloride concentration. The prism of soil would have to weigh 5,110 million pounds and have dimensions 842 feet square by 60 feet deep, or 584 feet square and 125 feet deep, extending to the water table. The potential for flows from a 40 foot square drainfield to permeate such extensive volumes is very small.

(2) Similarly, if a typical value for chloride ion increment due to domestic use of 40 mg/l is selected and the native groundwater is assumed to have 1.5 mg/l, then the total drainfield effluent quality would be 41.5 mg/l. Taking,

*µg/g - micrograms per gram.

for example, the observed moisture of approximately 2.5% by weight at 40 foot depth (in Hole No. CN-5), the computed chloride content of the soil, assuming this moisture to be drainfield percolate at 41.5 mg/l, is 1.04 μg/g. This compares with a measured value of 2 μg/g. Similarly, the mean for all observed moistures is 4.06% in Hole No. CN-1; the computed chloride content is 1.68 μg/g and the mean of the observed chlorides is 2.6 μg/g. These results indicate that the observed chloride concentrations in the soil moisture are about twice that expected of drainfield effluent. This suggests that about half of the drainfield moisture is traveling with all of its salt content and that there is no significant salt accumulation in the soil.

Site 2. This site (T25N,R44E,26N) was a dairy and was selected on the basis that it should have the highest pollution of this type in the Valley. Two test holes were drilled in the loafing area and one at a waste disposal site; in addition, a test hole was drilled in a nearby area for control. Hole depths ranged from 51 to 71 feet, while the water table was at a depth of 90 feet. Soil sampling and analysis procedures were identical to those at Site 1.

Sample results showed that bacteria were again rapidly removed in the upper soil layers. Chloride and nitrate were higher than at Site 1, but were still low and relatively uniform. Detergent analyses were negative; however, the tests were not considered conclusive.

Site 3. This site (T25N,R45E,7A) was a trailer park servicing six mobile homes; the pollution loading here was relatively light. Three test holes were drilled in the drainfield, which was adjacent to the Spokane River. Hole depths ranged from 31 to 43 feet, while the water table was at a depth of 45 feet. Soil sampling and analysis procedures were as before.

Sample results showed no bacteria below 6 feet; low and relatively uniform values of chloride, nitrate, detergents, and moisture were again observed, showing no evidence of salt accumulation.

Site 4. This site (T25N,R43E,14E) was located on the west side of a gravel quarry. Three test holes were drilled here as control holes for the drainfield study of the Valley. Hole depths penetrated to the water table at 67 feet. Soil sampling and analysis procedures were as before.

Sample results showed only one positive bacterial determination, negligible nitrate, and relatively uniform chloride values comparable to those found under drainfields in the Valley. Moisture contents again were low and relatively uniform.

Control borings had been made previously at both the nursing home and the dairy. In both cases, the chloride concentrations were found to be negligibly small. At the quarry site control borings, however, significant chlorides were found, the mean value for the two holes below 10 feet being 2.75 μg/g. This is the same magnitude as found under the two drainfields. The variability was extreme, for example, going from 5.51 μg/g at 51 feet to 0.63 μg/g at 61 feet. These results appear to be anomolous and are judged to not represent control conditions; past quarry operations which recycle wash waters into the quarry may have caused this condition.

<u>Summary</u>. Review of the studies by the Washington State University investigators indicates that their observed results are in basic agreement with the previously described analytic work. Specifically, chloride and nitrate concentrations in soils below septic tank drainfields were found to be generally low. With a net annual downward transport of septic tank effluent, precipitation, and irrigation waters, as computed herein, salt concentrations should remain low because of the leaching action of the percolating water moving to the water table.

Recommendations for Further Investigations

The analytic studies on groundwater quality are verified to a limited extent by available data as shown in Figure J and also by the earlier work of the Washington State University investigators (6,7,8). It would be desirable, however, to confirm and to extend these findings by additional field investigations. The purpose of the additional work would be to:

(1) Define more comprehensively the down-valley changes in groundwater quality.

(2) Obtain information on the variation in groundwater quality as a function of depth of penetration of wells.

(3) Provide a firmer foundation for future projections of groundwater quality and for wastewater management planning.

A field program should as a minimum consist of a series of well and water quality measurements along the flow line sketched in Figure K. Wells should be selected where it is possible to ascertain the following facts:

(1) Depth of water table at time of sampling.

(2) Depth of well and its penetration into the groundwater at the time of sampling.

(3) Location and size of openings in the well casing through

which groundwater enters the well.

(4) Elevation of the pump suction relative to the water table at time of sampling.

(5) Pumping rate at the time of sampling.

Where large diameter dug wells are available, it would be most useful to collect samples under quiescent conditions at various depths in the aquifer without pumping.

For each well sampled a complete physical description should be obtained in accordance with the above listing. The water quality sampling should, as a minimum, cover the following parameters:

(1) Temperature

(2) Conductivity, or total dissolved solids

(3) Chlorides

(4) Nitrate nitrogen

(5) Detergents

(6) Fecal coliform

It is recommended that the above described field investigational program be undertaken as soon as possible so that a more complete verification of the analytical results presented in this report can be achieved.

TABLE 1

Monthly Climatic, Evapotranspiration, and Soil Moisture Data for Spokane Valley

	J	F	M	A	M	J	J	A	S	O	N	D	YR.
Temperature, °F	26.7	32.0	40.3	48.1	55.8	61.8	69.9	67.0	60.1	49.5	37.5	31.1	48.3
Precipitation, in.	3.15	2.04	1.70	1.10	1.83	1.44	0.52	0.65	0.91	1.74	2.40	2.52	20.00
Potential Evapotranspiration, in.	0	0	0.61	1.71	3.14	4.38	5.61	4.78	3.15	1.67	0.46	0	25.51
Actual Evapotranspiration, in.	0	0	0.61	1.69	2.86	2.96	1.72	1.02	0.96	1.67	0.46	0	13.95
Moisture Deficit, in.	0	0	0	0.02	0.28	1.42	3.89	3.76	2.15	0	0	0	11.52
Soil Moisture Storage, in.	4.73	5.00	5.00	4.41	3.38	1.86	0.66	0.29	0.20	0.27	2.21	4.73	-
Snow Pack Moisture Storage, in.	3.15	0	0	0	0	0	0	0	0	0	0	0	3.15
Total Percolation, in.	3.15	1.77	1.09	0	0	0	0	0	0	0	0	0	6.01

TABLE 2
Monthly Water Balance Data for Spokane Valley under Generalized Suburban Conditions

	J	F	M	A	M	J	J	A	S	O	N	D	YR.
Precipitation and Septic Tank Effluent, in.	4.34	3.23	2.89	2.29	3.02	2.63	1.71	1.84	2.10	2.93	3.59	3.71	34.28
Potential Evapo-transpiration, in.	0	0	0.61	1.71	3.14	4.38	5.61	4.78	3.15	1.67	0.46	0	25.51
Actual Evapo-transpiration, in.	0	0	0.61	1.71	3.14	4.10	3.55	2.85	2.26	1.67	0.46	0	20.35
Moisture Deficit, in.	0	0	0	0	0	0.28	2.06	1.93	0.89	0	0	0	5.16
Soil Moisture Storage, in.	5.00	5.00	5.00	5.00	4.88	3.41	1.55	0.85	0.69	1.95	5.00	5.00	-
Snow Pack Moisture Storage, in.	3.15	0	0	0	0	0	0	0	0	0	0	0	3.15
Total Percolation, in.	4.34	3.23	2.28	0.58	0	0	0	0	0	0	0.08	3.71	14.22

TABLE 3

Normal Ranges of Increases in Inorganic Salts in Domestic Sewage (3)

Mineral	Mineral range (mg/1)
Dissolved solids	100 - 300
Boron (B)	0.1 - 0.4
Sodium (Na)	40 - 70
Potassium (K)	7 - 15
Magnesium (Mg)	3 - 6
Calcium (Ca)	6 - 16
Total Nitrogen (NO_3)	20 - 40
Phosphate (PO_4)	20 - 40
Sulfate (SO_4)	15 - 30
Chloride (Cl)	20 - 50
Alkalinity (as $CaCO_3$)	100 - 150

TABLE 4

Summary of Annual Water Balance and Percolation Quality Values for Spokane Valley Planning Units at Present (1975)

	Planning Unit				
	SV3	SV5	SV6	SV7	SV8
Mean Annual Precipitation, in.	19.5	21.[illegible]	21.0	22.0	22.0
Septic Tank Effluent, in.	3.95	0.74	0.70	0.16	0.16
Lawn Irrigation, in.	8.05	6.06	2.26	0.98	1.67
Agricultural Irrigation, in.	0.72	7.27	6.44	5.67	5.19
Total Applied Water, in.	32.22	33.07	30.40	28.81	29.09
Percolation, in./yr.	11.11	10.91	8.47	8.16	8.24
Flow Length, ft.	37,500	7,700	4,000	18,000	12,600
Flow Line Percolation, in.	18.1	3.66	1.48	6.38	4.51
TDS of Percolation, mg/l	302	240	222	162	165

TABLE 5
Population Trends in Spokane Valley

Planning Unit		1975 Population	2020 Population
SV-3		30,000	43,800
SV-5		2,000	3,267
SV-6		1,000	1,575
SV-7		1,900	3,560
SV-8		2,300	5,190
	Total	37,200	57,392

TABLE 6
Summary of Annual Water Balance and Percolation Quality Values for Spokane Valley Planning Units at Year 2020

	Planning Unit				
	SV3	SV5	SV6	SV7	SV8
Mean Annual Precipitation, in.	19.5	21.0	21.0	22.0	22.0
Septic Tank Effluent, in.	6.34	1.31	1.07	0.36	0.48
Lawn Irrigation, in.	10.09	4.60	2.95	1.72	2.54
Agricultural Irrigation, in.	0.21	4.71	2.99	4.75	3.33
Total Applied Water, in.	36.14	31.62	28.01	28.83	28.35
Percolation, in./yr.	15.39	9.42	8.09	8.68	8.31
Flow Length, ft.	37,500	7,700	4,000	18,000	12,600
Flow Line Percolation, in.	25.1	3.16	1.41	6.79	4.55
TDS of Percolation, mg/l	304	239	200	160	162

TABLE 7A
SELECTED GROUNDWATER QUALITY AND
WELL DATA FOR SPOKANE VALLEY
SEPTEMBER 1973

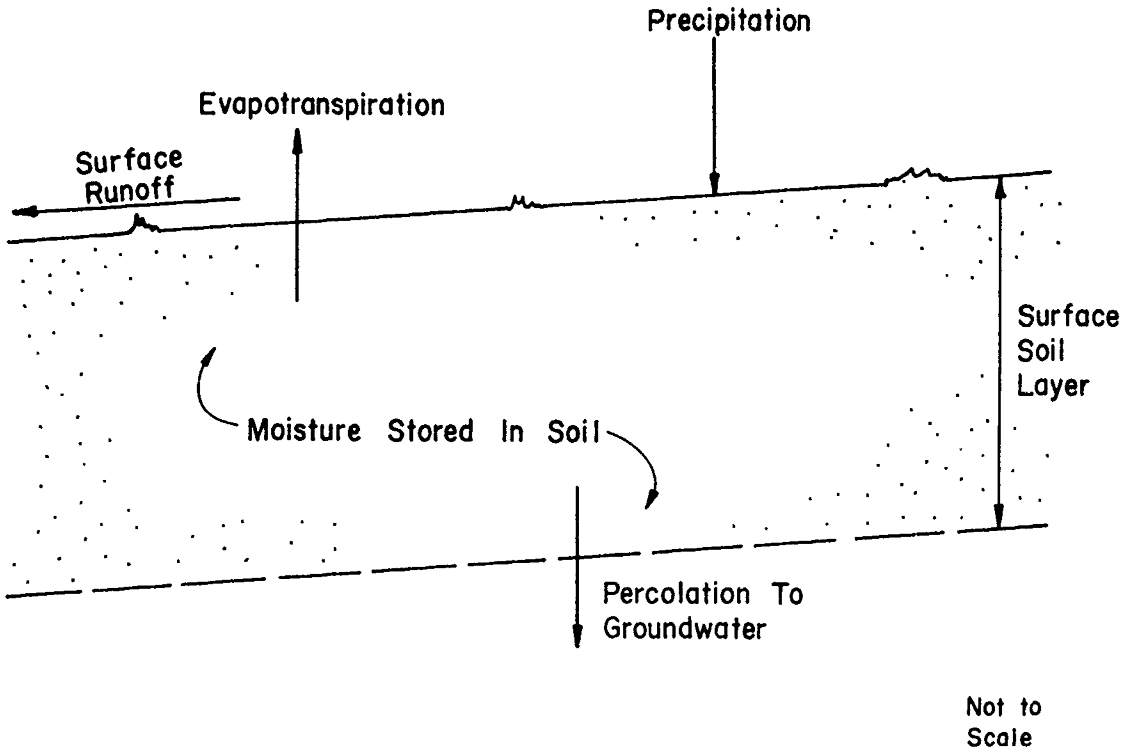
Well Location	Well Penetration below Water Table, ft.	TDS, mg/1*	Distance from Idaho State Line, mi.
26/45, 36Q1	-3	155	0.7
26/45, 36N1	23	158	1.1
26/45, 35F1	117	151	1.8
25/45, 15D1	75	157	3.1
25/44, 1J1	77	160	6.9
25/44, 2Q1	45	174	7.6
25/44, 7C1	31	206	11.9
25/44, 18D1	42	193	12.1
25/44, 19D1	8	206	12.1
25/43, 13A1	41	170	12.3
25/43, 14K1	31	152	13.6

*Source USGS-EPA Program measured on September 25-26, 1973.

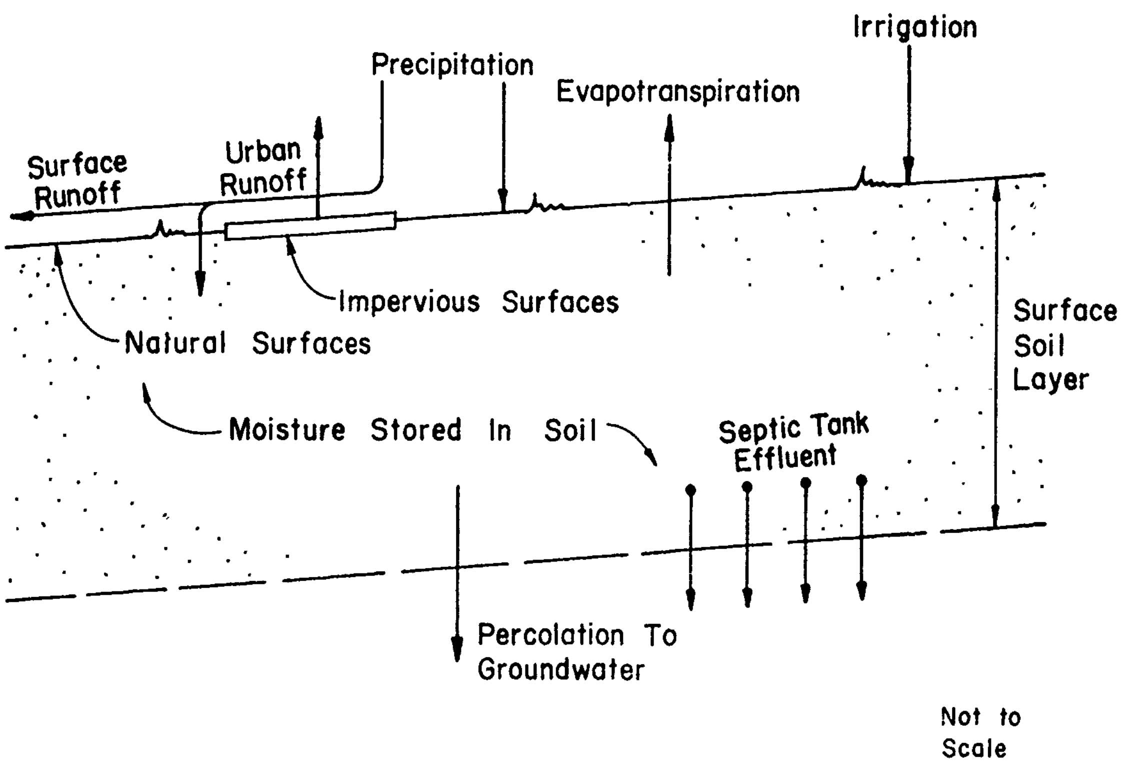
TABLE 7B
SELECTED GROUNDWATER QUALITY AND
WELL DATA FOR SPOKANE VALLEY
SEPTEMBER 1971-72

Well Location	Well Penetration below Water Table, ft.	TDS, mg/1*	Distance from Idaho State Line, mi.
26/46, 31M	110	120	0.2
25/45, 15D1	75	155	3.1
25/45, 18R	130	105	5.5
25/44, 26L1	0-32**	195	7.8
25/44, 27E1	63	164	9.3
25/44, 16E1	28	174	10.2
25/44, 29A1	5-26**	206	10.5
25/43, 12H1	35	210	12.3
25/43, 24L	9	216	12.8
25/43, 23A1	80	182	13.3
25/43, 23A2	74	196	13.3

*Source: Spokane County Health District
Mean values for September 1971 and 1972 computed from r [illegible]ted conductivity using a factor of 0.56.
**Perforated casing.

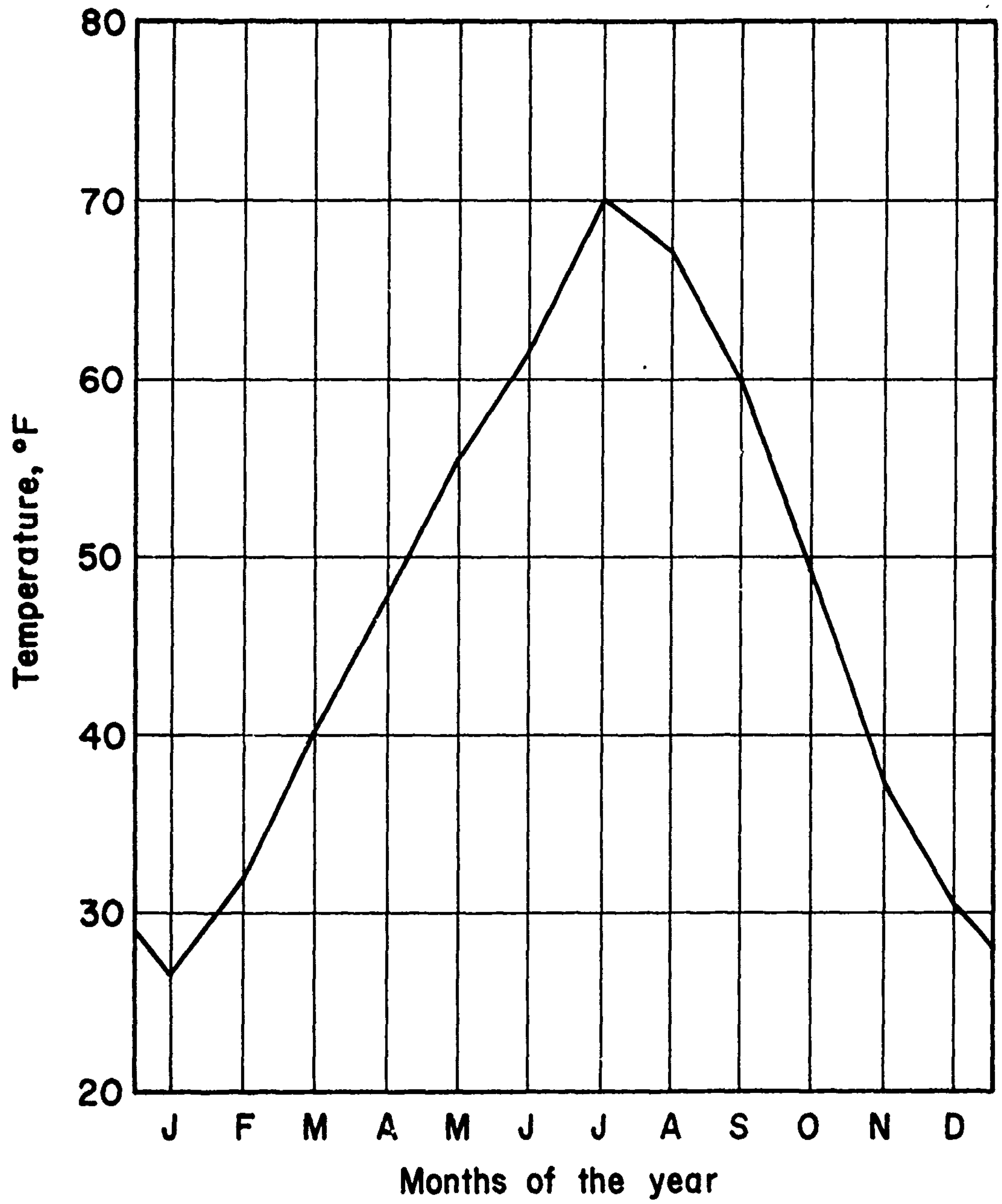


NATURAL CONDITIONS

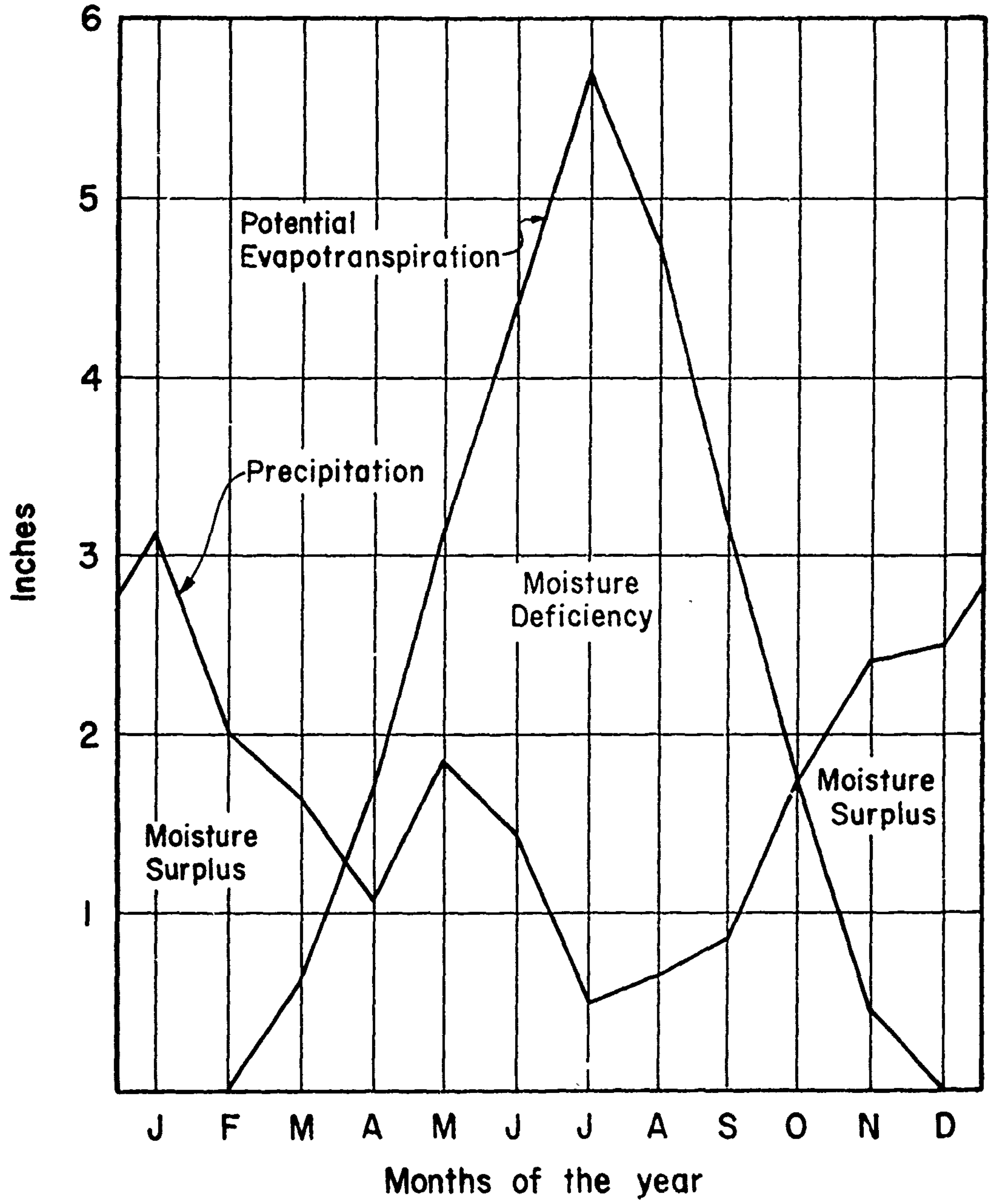


DEVELOPED CONDITIONS

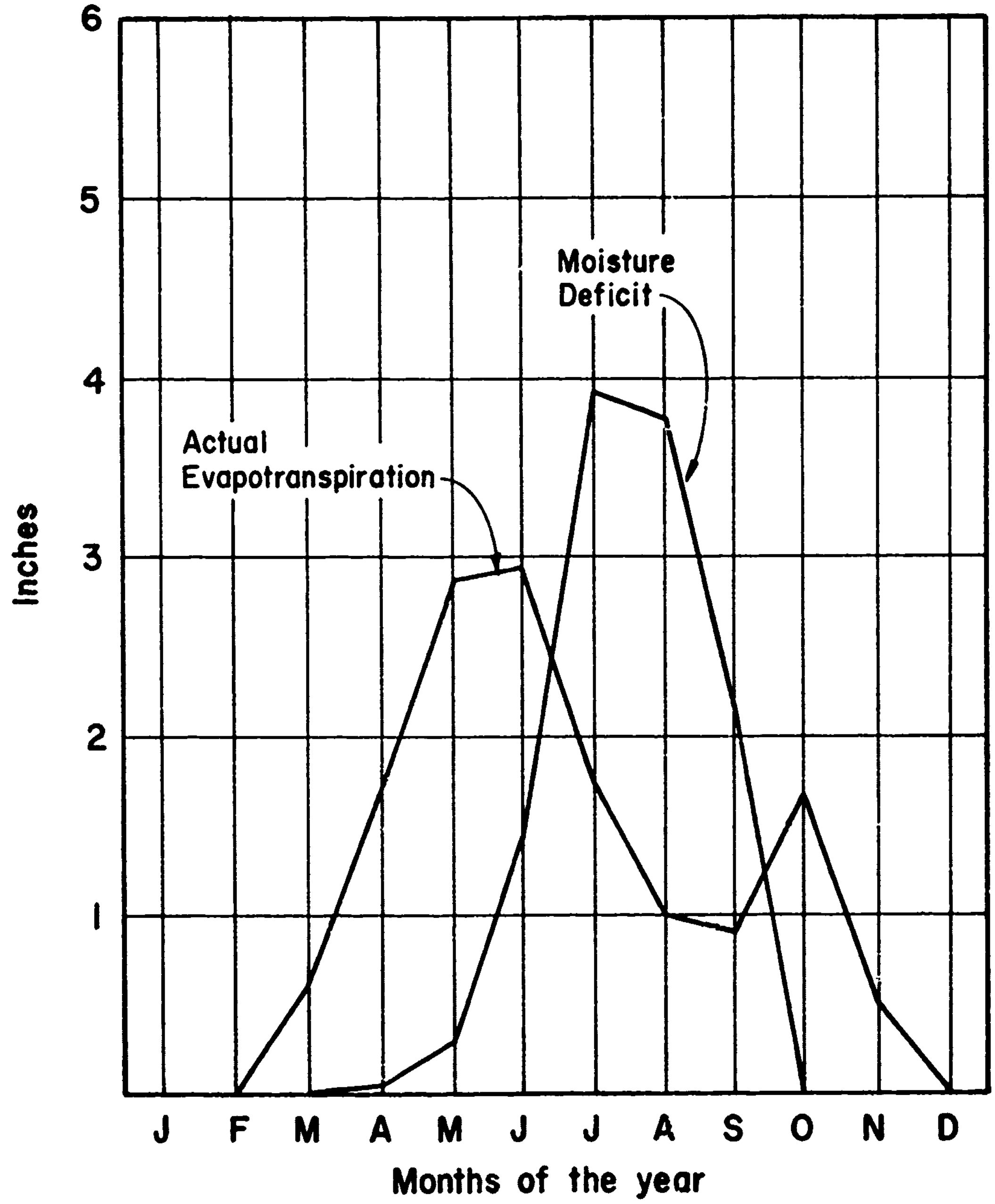
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Schematic Diagram of Water Balance for a Surface Soil Layer under Natural and Developed Conditions	Figure A



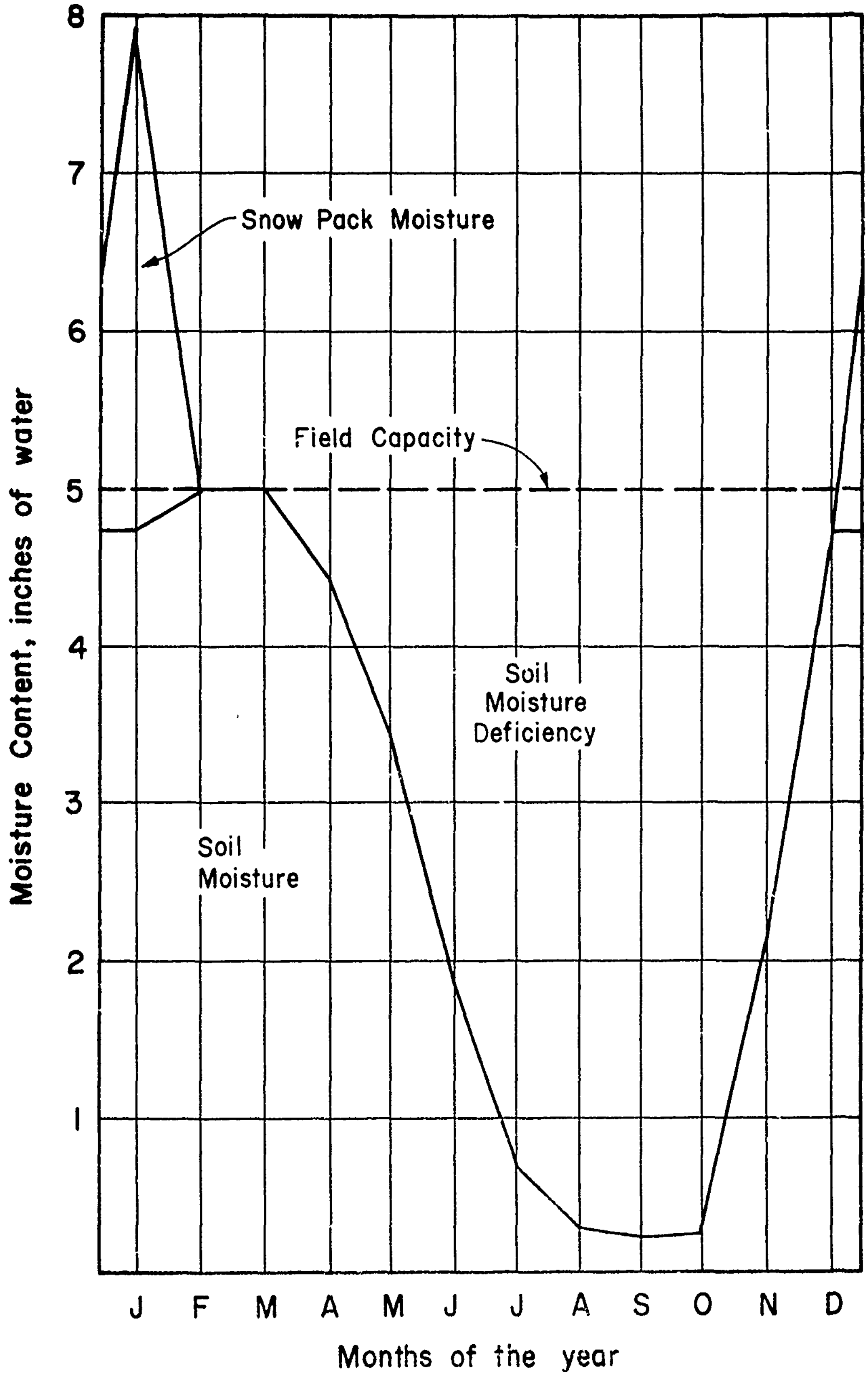
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Monthly Mean Air Temperatures for Spokane Valley	Figure B



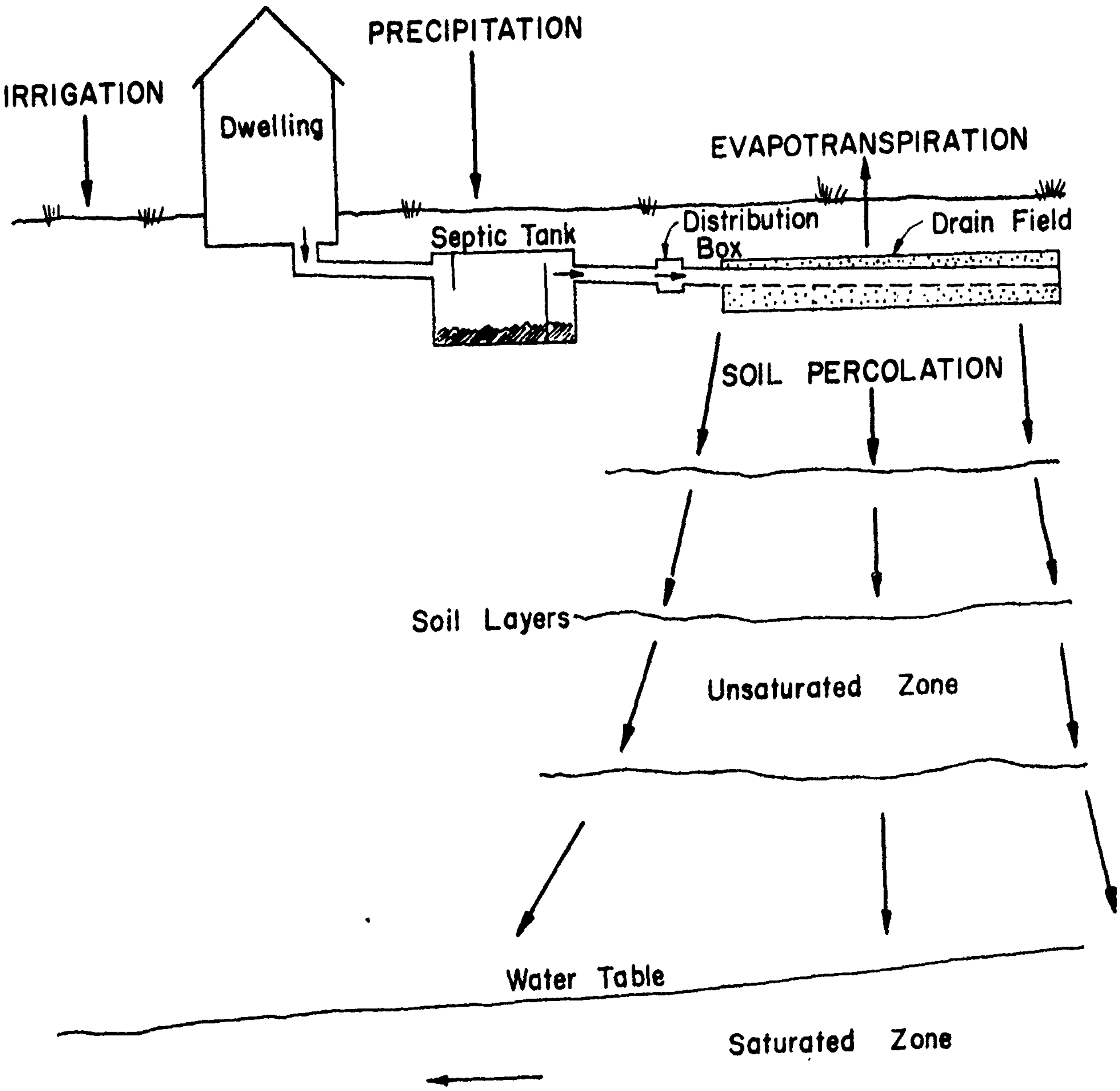
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Monthly Mean Precipitation and Potential Evapotranspiration for Spokane Valley	Figure C



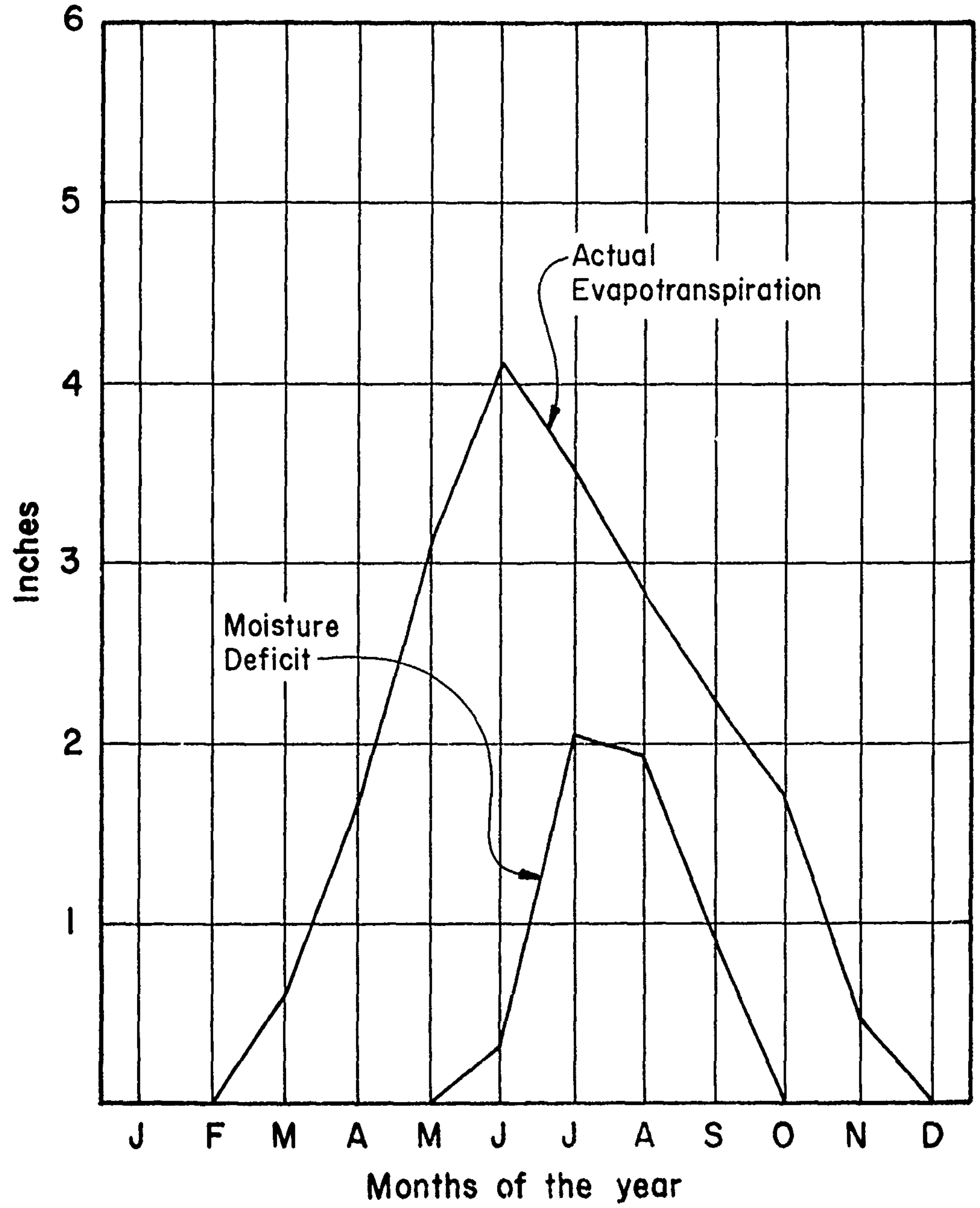
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Monthly Actual Evapotranspiration and Moisture Deficit for Natural Conditions in Spokane Valley	Figure D



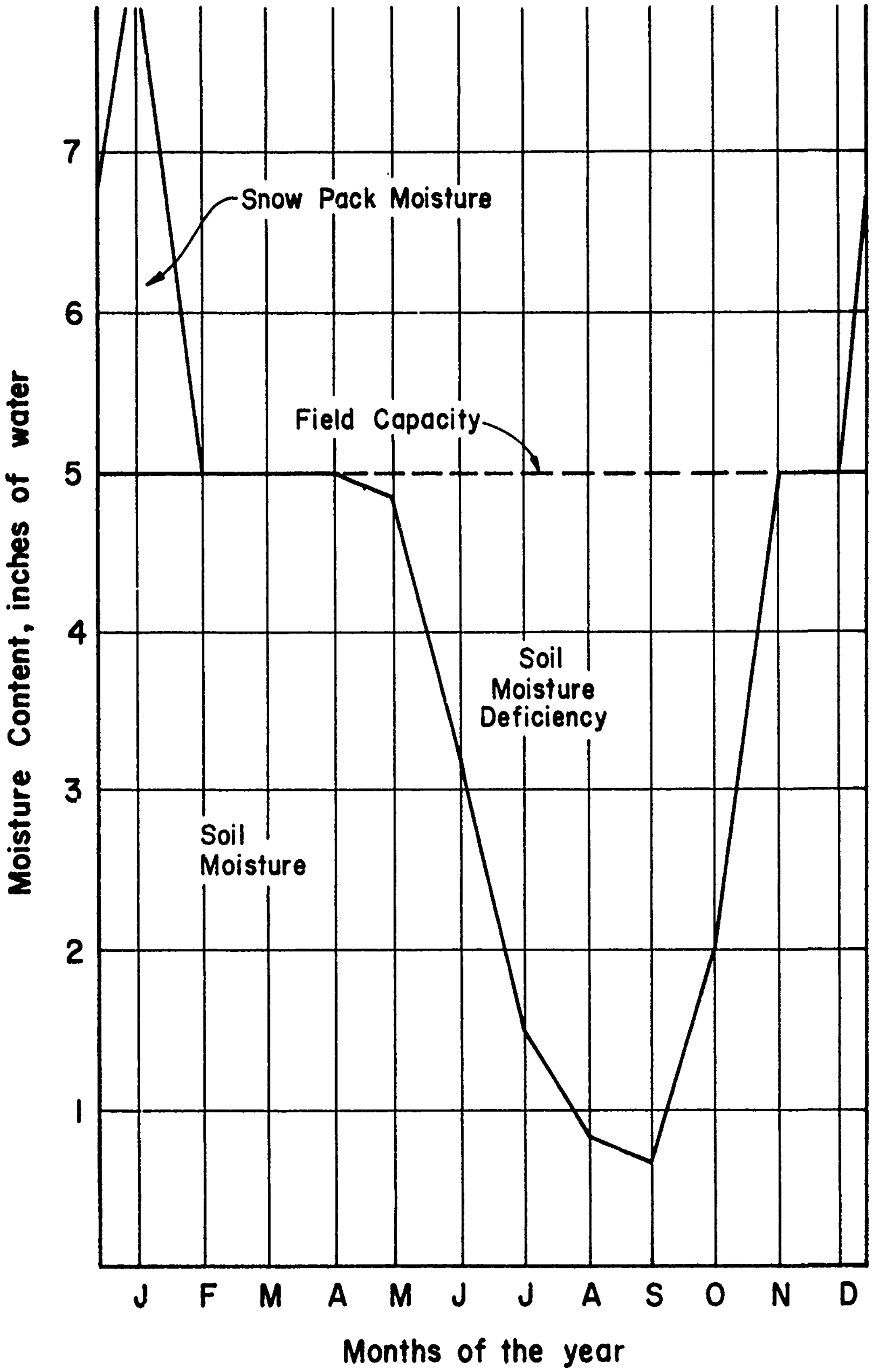
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Monthly Soil and Snow Pack Moisture Storage for Natural Conditions in Spokane Valley	Figure E



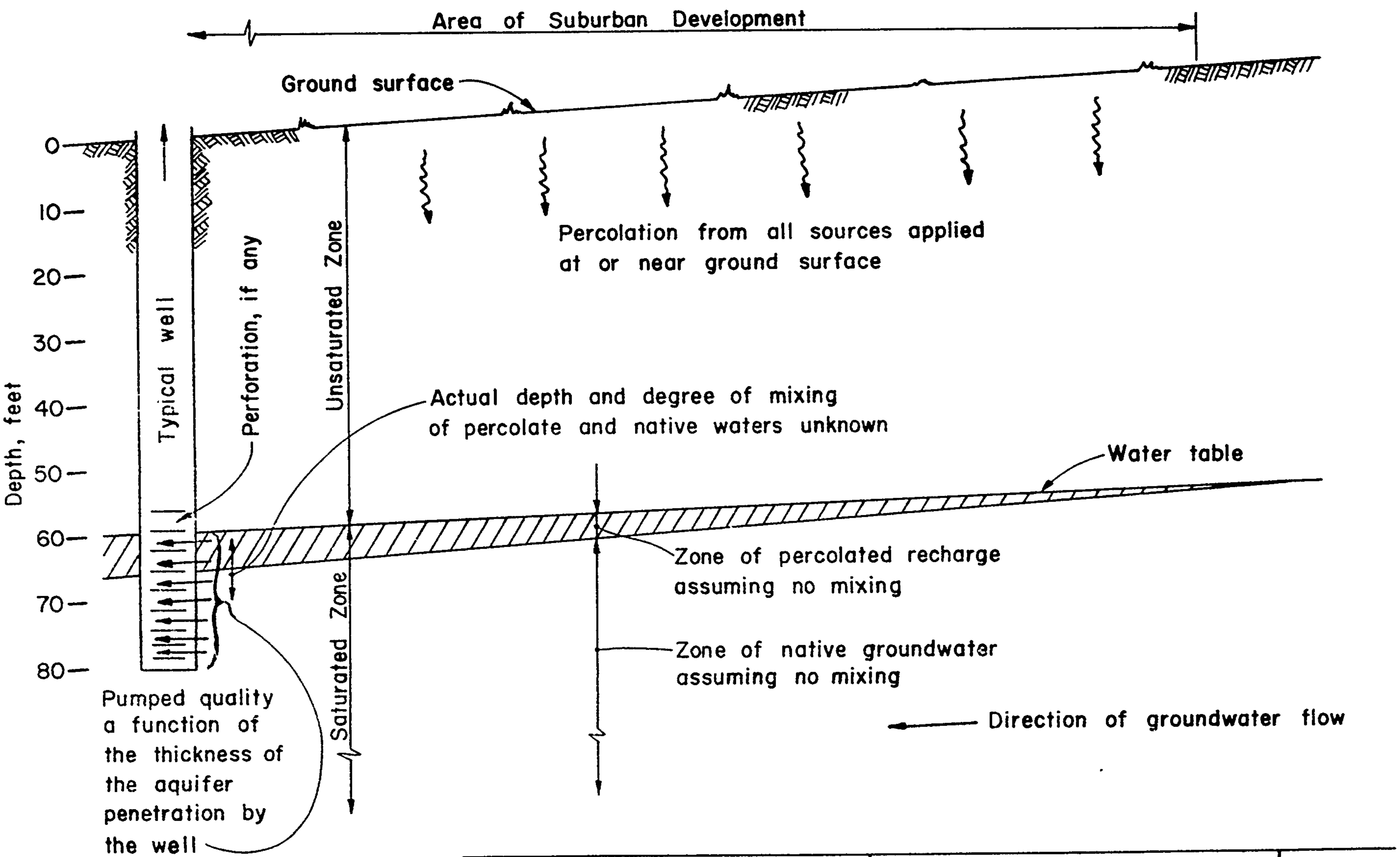
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Disposal of Household Wastewater through a Conventional Septic Tank - Drainfield System	Figure F



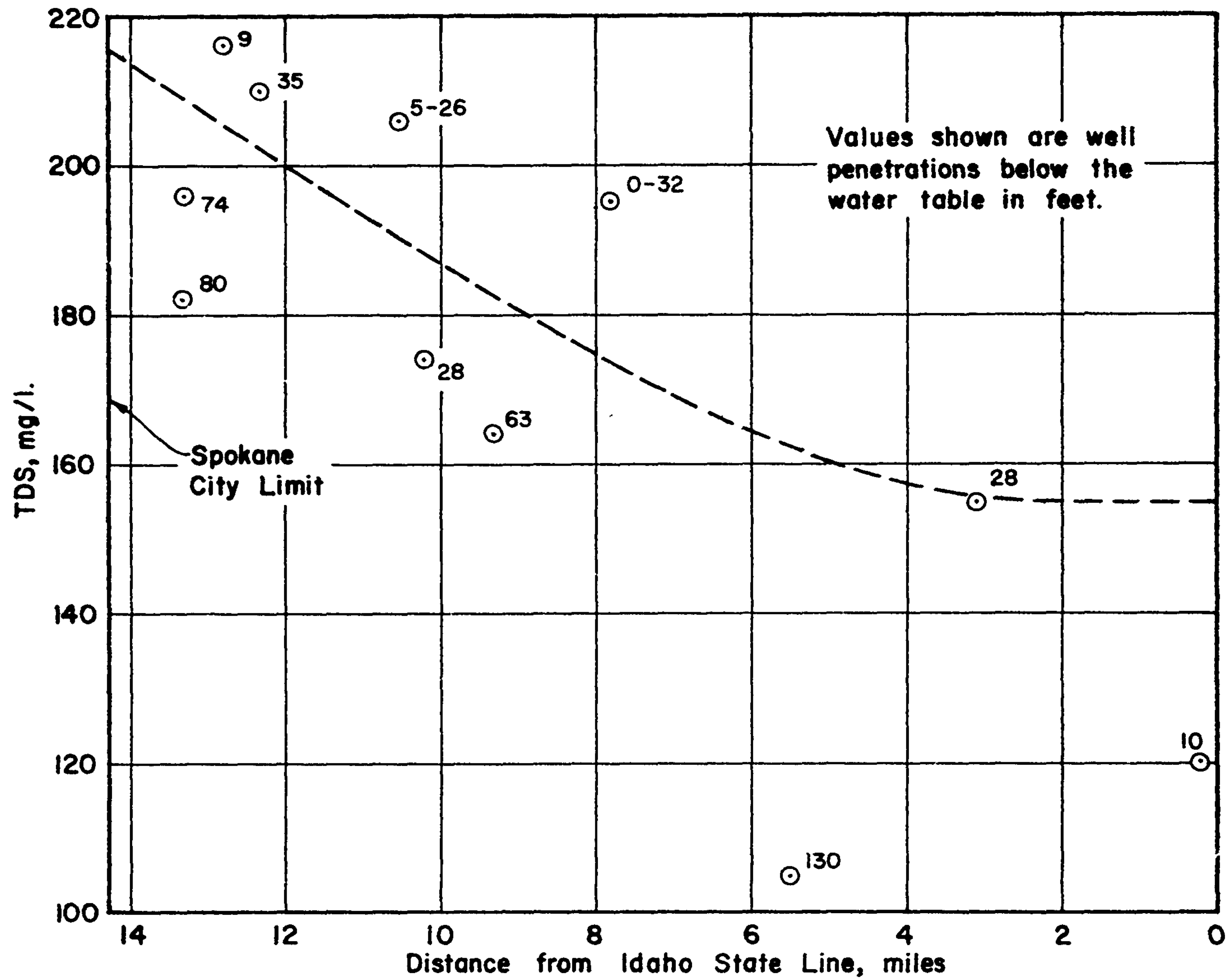
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Monthly Actual Evapotranspiration and Moisture Deficit for Spokane Valley under Generalized Suburban Conditions	Figure G



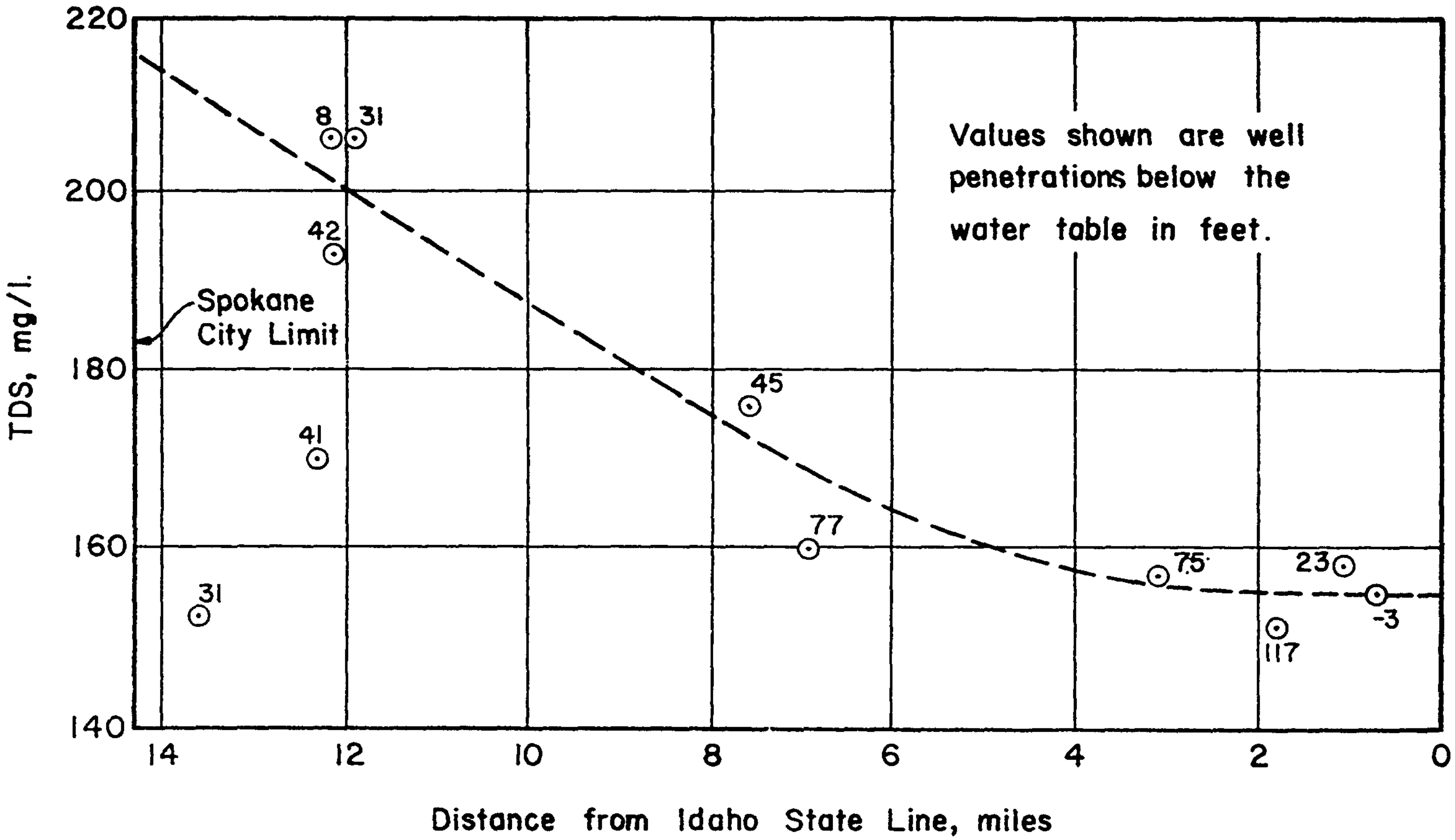
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Monthly Soil and Snow Pack Moisture Storage for Spokane Valley under Generalized Suburban Conditions	Figure H



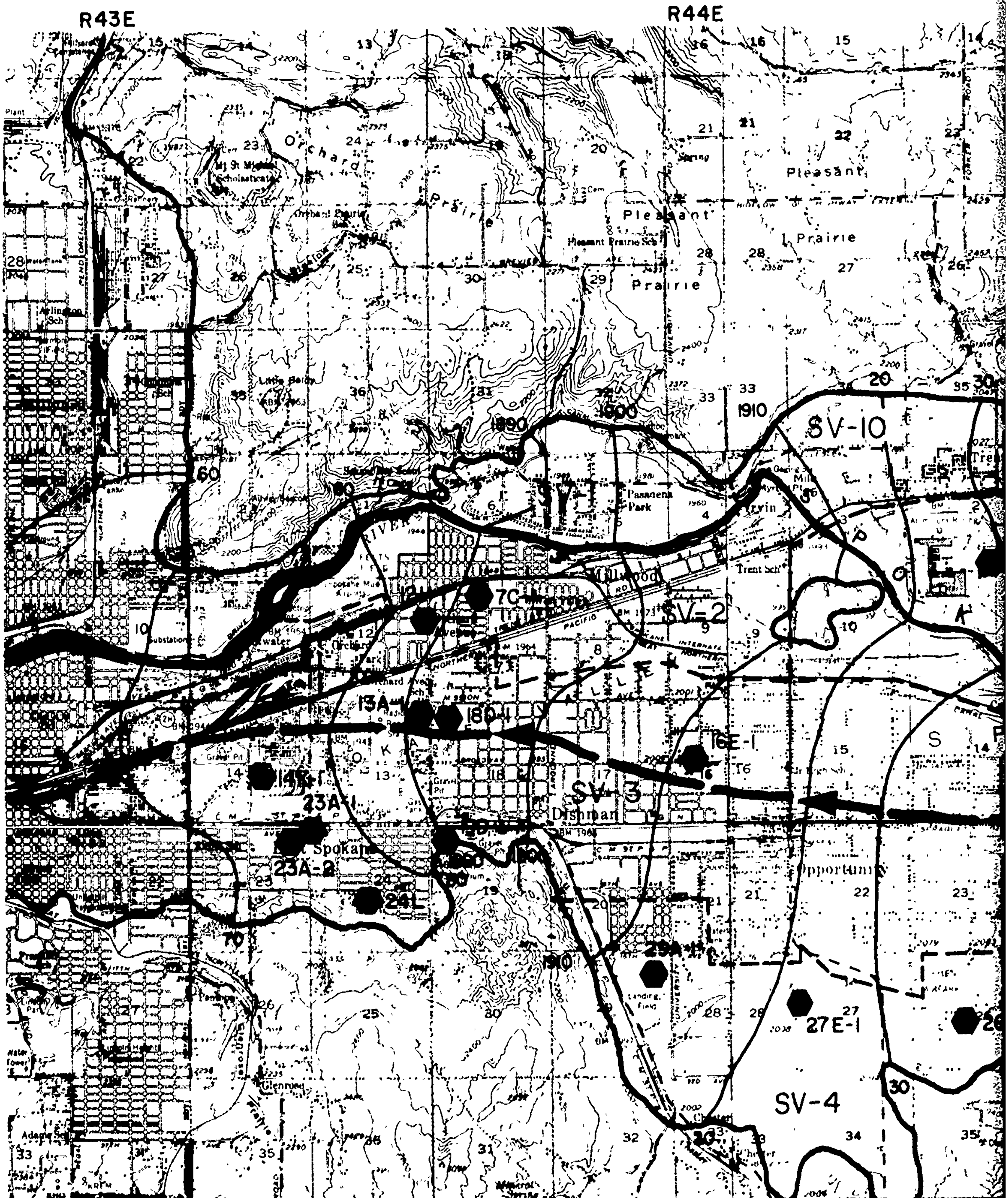
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy – Tudor Consulting Engineers	Vertical Cross-section Showing Estimated Movement of Groundwater to a Typical Well in Spokane Valley	Figure I



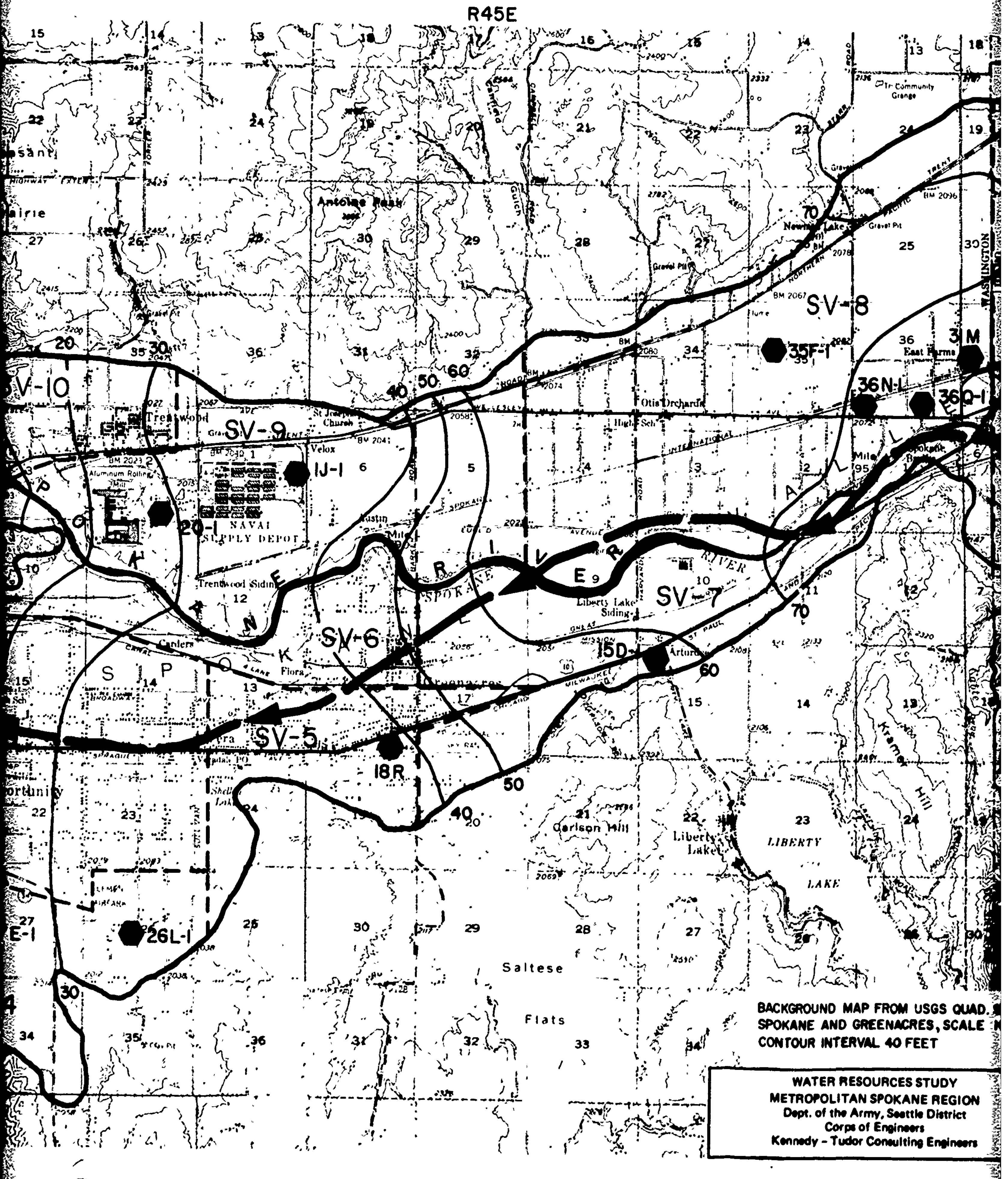
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Variation in Measured Salinity of Groundwater in Spokane Valley as a Function of Distance from the Idaho State Line September 1971-72	Figure J-2



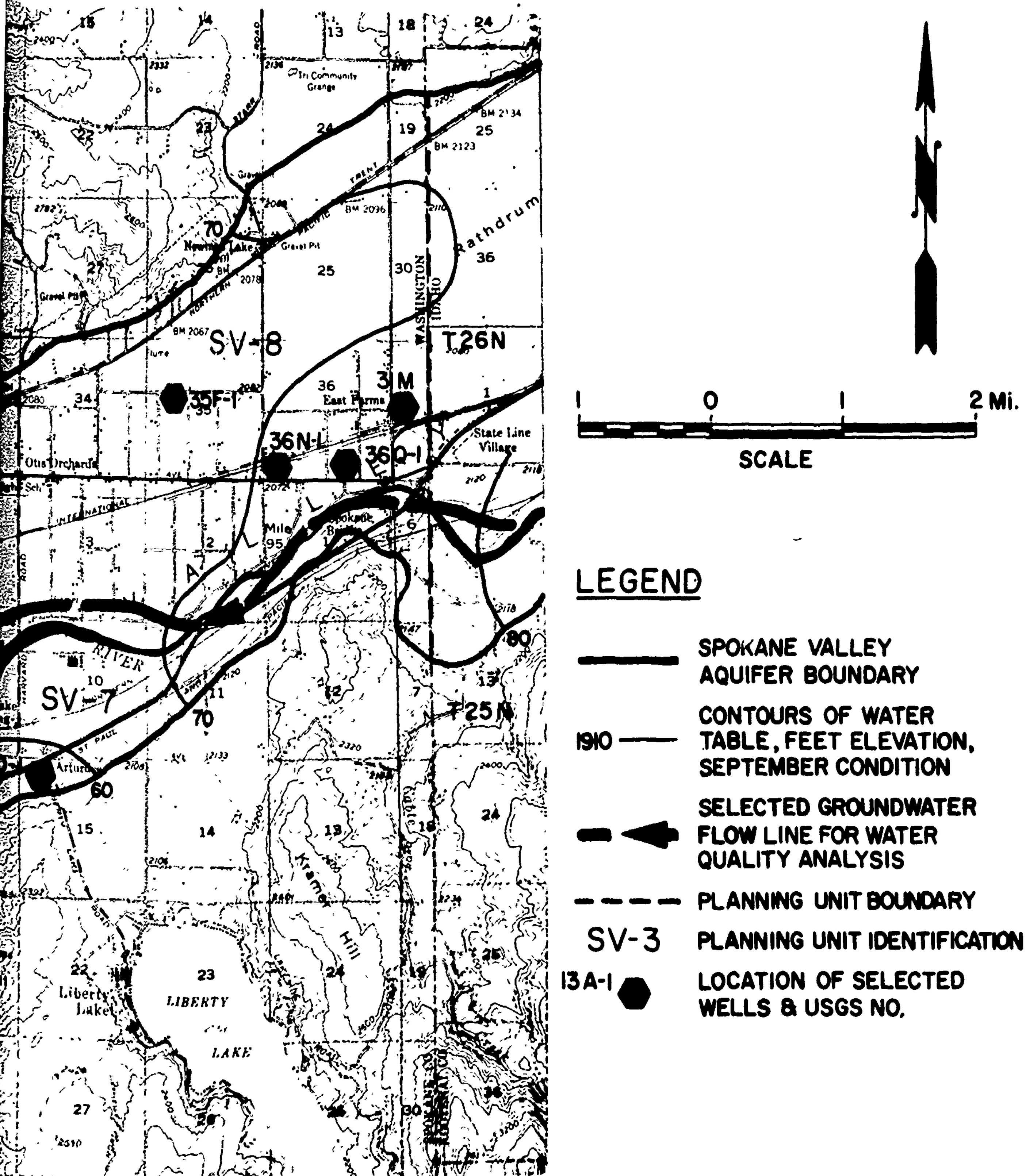
WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Bept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	Variation in Measured Salinity of Groundwater in Spokane Valley as a Function of Distance from the Idaho State Line September 1973	Figure J-1



R43E
R44E
Orchard Prairie
Pleasant Prairie
Pleasant Prairie Sch
Mt St Michael Scholasticate
Little Baldy
Pasadena Park
Irvin
Millwood
Trent Sch
Dishman
Spokane
Opportunity
Glenrose
SV-10
SV-1
SV-2
SV-3
SV-4
7C
13A-1
18D-1
16E-1
23A-1
23A-2
24L
27E-1
1890
1900
1910



WATER RESOURCES STUDY
METROPOLITAN SPOKANE REGION
Dept. of the Army, Seattle District
Corps of Engineers
Kennedy - Tudor Consulting Engineers



BACKGROUND MAP FROM USGS QUAD. SHEETS FOR SPOKANE AND GREENACRES, SCALE 1:62,500
CONTOUR INTERVAL 40 FEET

WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	SPOKANE VALLEY WATER TABLE CONTOURS AND GROUNDWATER FLOW LINE	FIG. K

LIST OF REFERENCES

(1) Wernstedt, F.L., World Climatic Data, Climatic Data Press, 1972.

(2) Thornthwaite, C.W., and J. R. Mather, Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance, Lab. of Climatology, Drexel Inst. of Technology, Publs. in Climatology, v.X, no. 3, 311 pp., 1957.

(3) Miller, D. W., et al., Ground Water Contamination in the Northeast States, U.S. Environmental Protection Agency, Washington, D.C., June 1974.

(4) Laak, R., et al., Rational basis for septic tank system design, Ground Water, v. 12, no. 6, pp. 348-352, November -December 1974.

(5) Pitt, W.A., Jr., Effects of septic tank effluent on ground-water quality, Dade County, Florida: An interm report, Ground Water, v. 12, no. 6, pp. 353-355, November-December 1974.

(6) Crosby, J.W., III, et al., Migration of pollutants in a glacial outwash environment, Water Resources Research, v. 4, no. 5, pp. 1095-1114, October 1968.

(7) Crosby, J.W., III, et al., Migration of pollutants in a glacial outwash environment, 2, Water Resources Research, v. 7, no. 1, pp. 204-208, February 1971.

(8) Crosby, J.W., III, et al., Migration of pollutants in a glacial outwash environment, 3, Water Resources Research, v. 7, no. 3, pp. 713-720, June 1971.

(9) Weigle, J.M., and Mundorff, M.J. Records of Wells, Water Levels, and Quality of Ground Water in the Spokane Valley, Spokane County, Washington. U.S. Geological Survey, Tacoma, Washington. Sept. 1952.